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AGRICULTURAL ENGINEERING

AUGUST · 1947

Basic Principles in the Drying of Corn and Grain Sorghum *Wm. V. Hukill*

Some Results of Research Work in Chemical Weed Control *H. T. Barr, C. A. Brown*

Coordinating Research of Interest to Agriculture and Industry *H. A. Lyon*

Use of Insulation Board in Poultry Laying Houses *H. B. White, A. R. Schwantes*

Recommendations for Mechanical Conditioning of Soft Corn *Committee Report*

THE JOURNAL OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

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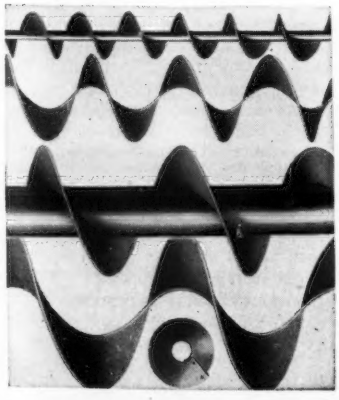

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AGRICULTURAL ENGINEERING

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CONTENTS FOR AUGUST, 1947

Vol. 28, No. 8

EDITORIAL 333

BASIC PRINCIPLES IN DRYING CORN AND GRAIN SORGHUM 335
By William V. Hukill

CHEMICAL WEED AND PLANT CONTROL 339
By W. C. Dutton

WEED CONTROL WITH 2,4-D 341
By Harold T. Barr and Clair A. Brown

COORDINATING RESEARCH AND DEVELOPMENT OF JOINT INTEREST TO AGRICULTURE AND INDUSTRY 343
By H. A. Lyon

AGRICULTURAL ENGINEERS IN WATER MANAGEMENT 345
By John A. Short

BUILDING A SOIL DEEPER 347
By D. D. Smith, C. M. Woodruff, and D. M. Whitt

SOIL EROSION STUDIES — PART V 349
By W. D. Ellison

RECOMMENDATIONS FOR MECHANICAL CONDITIONING OF SOFT OR HIGH-MOISTURE CORN 352

EFFECT OF VARIATION IN SOIL WATER ON YIELD AND QUALITY OF POTATOES 353
By J. F. Cykler

USE OF INSULATION BOARD IN LAYING HOUSES 354
By H. B. White and A. R. Schwantes

SPREADER ROOM ADDED TO DAIRY BARNS (Letter) 363
By R. W. Westerberg

RESEARCH NOTES 363

NEWS SECTION 364

PERSONNEL SERVICE BULLETIN 372

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RAYMOND OLNEY
Editor and Business Manager

EDITORIAL

Emergency Action

POTENTIALITIES of the American Society of Agricultural Engineers, as an organization for timely action in cases of forseeable emergencies, were strongly reemphasized by the recent Conference on Conditioning the 1947 Corn Crop.

The Conference was planned and attended largely by A.S.A.E. members, with the cooperation of the U. S. Department of Agriculture, state agricultural experiment stations, farm equipment manufacturers and others.

Its purpose was to anticipate the need of special precautions to save a maximum amount of the year's corn crop, in view of its delayed start and the resulting probability of frost damage before normal ripening.

By bringing together for this specific purpose most of the leading authorities on corn harvesting and handling, the Conference was able to boil down their combined experience and viewpoints into three mimeograph pages of recommendations covering a wide range of conditions and situations. These were quickly made available to farmers and grain dealers, in time to enable them to decide what they can best do, and to take preliminary action to prepare for the emergency. Corn growers and handlers can take steps to make the best of the situation, whatever the weather may do to the crop during the next few months.

Other emergencies in the production and handling of farm crops and livestock, and in the conservation of other agricultural values, can be anticipated. Some of them will involve agricultural engineering.

The service rendered by individual agricultural engineers, and the usefulness of the American Society of Agricultural Engineers, will be increased if we all keep in mind that it is a ready-made, flexible, and readily available organization for coordinating group thought and action in emergencies where the technology and application of agricultural engineering are involved.

An Influence for Engineering Progress

IT IS a distinct pleasure to invite attention to a young and small but growing contemporary organization which is showing strong leadership in the economic matter of giving the customer his money's worth. Its members are in the business of applying agricultural engineering principles, with the aid of engineered equipment.

It is the 9-year-old Missouri Terracing and Conservation Contractors' Association, whose members police themselves, guarantee their work, correct their mistakes, and refuse work which they know, better than the landowners concerned, cannot give satisfaction.

In basic economic terms these Missouri contractors are increasing the net efficiency and advantages of specialized production, the form of economic activity in which engineering shows up to best advantage.

One major weakness of specialized production is that none of us can possibly know as much about the thousands of products and services we buy and use, as do their respective producers, or as we may about the one or few items or services which we produce and sell. The producer is far better qualified than the purchaser, in most cases, to see that the purchaser gets his money's worth.

Thus if we are to realize anywhere near the full potential advantage of specialized production, in terms of user satisfaction, the users in most cases will need to be well and soundly advised by producers. And the producers will need to be so concerned about user satisfaction that they will permit the purchase and use of their goods and services only under conditions which offer strong promise of such satisfaction being realized.

Business and professional leaders have long since abandoned the old Roman dictum of "caveat emptor," but enough people still cling to it to reduce the potential benefits of specialization and exchange by untold billions of dollars a year in the United States alone, in the cost of business swindles, shady deals, and government policing of business.

It is to be expected that many producers will likewise be slow to adopt the positive and more advanced philosophy of going far beyond the requirements of common honesty to give the benefit of their specialized knowledge of their goods or services to buyers, at the expense of immediate sales. The "dollar-in-hand" temptation is strong.

But the idea will spread. The fact that some groups have adopted it; have developed effective organizations and procedures for policing themselves; and have found it profitable, will attract others to the idea. Customer approval and competition will help it gain ground, particularly among producers of major services and durable goods, with tangible values subject to the minimum of style influence, personal prejudice, and individual whims of the purchaser. Ultimately it might even supplant, in some measure, the convivial school of salesmanship.

We congratulate the Missouri Terracing and Conservation Contractors' Association on being among the leaders in this progressive and constructive practice, and are happy that one field of applied agricultural engineering is thus represented.

Work-Flow-Chart Applications in Agriculture

A DISTINCTIVE contribution to agricultural engineering technique is reported elsewhere in this issue in the address of H. A. Lyon on the activities of the Detroit Agricultural-Industrial Foundation.

This technique is the work-flow-chart approach to analysis of farm operations. It gets down to specific, measurable objectives in terms of time, position, motion, condition, changes to be accomplished, and logical step-by-step order of procedure with respect to the material in process, end product, or result of any specific operation. It is a proven device for steering engineering thought in profitable channels in the analysis of production problems.

Application of this technique to the study of farm operations may not be entirely new. It is still new enough, however, that it took a matter of months for some agricultural engineers, dairymen, and other scientists to arrive at substantial agreement on the action requirements for the one specific operation of getting milk from cow to cooling room. It is hoped that this preliminary study may reveal a pattern of essentials applicable to other operations, and useful to simplify their analysis.

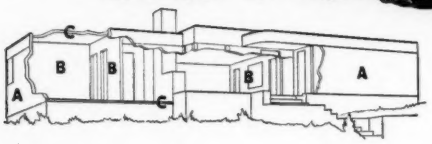
Mr. Lyon suggests three general types of results from such studies, namely, type and arrangement data on buildings and structural equipment, information as to farm operations most susceptible to profitable mechanization, and information for users on capacities of present equipment.

It occurs to us that there may be at least two additional important results. The information produced should give manufacturers a clearer picture than ever before of the functional requirements of present and proposed farm equipment. Further, the attempt to actually get down to the bed-rock foundation of reason for certain farm operations and for doing them in one specific way rather than another, can be expected to reveal points at which this bedrock foundation of reason has not yet been uncovered by physical or biological science. Some important problems for research may thus be revealed and clearly defined.

The work-flow-chart technique provides an unusually clear-cut opportunity for agricultural engineering liaison between agriculture and other industries. It shows promise of early results which may put agricultural engineers under considerable pressure to keep up on developments and meet the demand for service. It is applicable to all technical branches of agricultural engineering. A number of agricultural engineers may find it worth while to give increased thought to its problems and opportunities.

A Prize House in '40
... but what about today?

The prize home in Spokane, Washington, as it looked in 1940, shortly after taking first award in a competition sponsored by the Spokane Chamber of Commerce.



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[A] *The smooth, attractive exterior surface is of 3/8" Exterior-type Douglas fir plywood, applied in vertical panels with joints carefully butted. Exterior-type plywood is made with completely waterproof phenolic resin binder, especially for permanent application.*

[B] *Interior-type plywood was used on interior walls and ceilings. Joint-free finishes were attained in kitchen and bath by covering panels with muslin and painting over. One bedroom was papered. The second bedroom and living room panels were painted.*

[C] *Plyscord (the sheathing grade of interior type Douglas fir plywood) was specified for rigid, durable roof sheathing. Plywood was also used under the linoleum in kitchen and bath, for a smooth, cupless, ridgeless base.*

PLYWOOD'S MANY ADVANTAGES KEEP DEMANDS GREATER THAN PRESENT SUPPLIES

Douglas fir plywood production is greater now than in prewar years. Today's demand, however, is unprecedented—and raw material availability is the controlling factor in attaining higher output. This uneven demand-supply ratio naturally means that plywood may not always be readily obtainable at any given time and place. Keep in touch with your regular source of supply as to price and delivery information. For technical data, write the Douglas Fir Plywood Association, Tacoma 2, Washington.

"one of my most successful houses"
says Architect Edwin J. Peterson,

"AFTER SEVEN YEARS, IN PERFECT CONDITION—INSIDE AND OUT"

BUILT in 1940, this attractive home demonstrates the many advantages to be gained through Douglas fir plywood Dri-bilt construction. Architect Edwin J. Peterson of Spokane used plywood for both interior and exterior surfaces because it lent itself so admirably to his clean-cut, modern design and provided permanent wall surfaces that would withstand extremes in temperature. The plan was laid out on 4-foot modules, taking advantage of the erection-economy offered by standard 4'x8' panels. Mr. Peterson says: "After seven years, this house is in perfect condition. The interior panels proved to be excellent for a variety of finishes, such as the plain painted living room, the papered bedroom and the canvas-covered bath."

Douglas Fir
PLYWOOD
LARGE, LIGHT, STRONG
Real Wood
Panels

AGRICULTURAL ENGINEERING

VOL. 28 AUGUST, 1947 NO. 8

Basic Principles in Drying Corn and Grain Sorghum

By William V. Hukill

MEMBER A.S.A.E.

AN ANALYSIS of the factors affecting the economic operation and design of grain driers requires the segregation of several separate sets of costs. Each of the classes of costs may be broken down independently of the others and the total cost estimated. These costs may be classed as follows: (1) Cost of owning equipment; (2) cost of labor for operation, including handling of grain; (3) cost of power; (4) cost of heat, and (5) cost represented by reduced value of grain if damage takes place. All of these costs are affected one way or another by the length of time required for the drying process. Rates of drying have been measured for a large number of drying conditions with different grains. However, there are very few quantitative data on the effects of each of the various factors involved on drying rate.

It is the purpose of this paper to enumerate the factors affecting drying rate and suggest a method by which they may be combined in computations of approximate drying time, and to report the results of a few tests with ear corn and grain sorghum.

In a simple batch drier, grain is placed in a bin and heated air is forced through it until the desired moisture content is reached. In this type of drier, the grain at the air intake side, frequently the bottom of the bin, dries most rapidly and that where the air leaves takes the longest to dry. It has frequently been observed that drying may take place in a narrow layer of grain at the intake side and this layer may be dried almost to completion before other layers have lost any moisture. In this case the layer of grain where drying is taking place has been called the "zone of drying". The zone of drying progresses through the grain in the direction of air movement until it finally has passed through all the grain, and drying is completed. Other observers have noted that drying starts immediately in all the grain, although it takes place most rapidly where the air enters. In the latter case the zone of drying includes all the layers of grain.

When the heated air enters the grain in such a drier the first layer of grain gives up some of its moisture to the air. When this wetter air gets to the next layer it has less drying capacity, so drying is less rapid. As it moves through the grain its capacity for picking up moisture becomes less and less. If it leaves the grain before coming to moisture equilibrium with it, the grain at all levels will dry from the start. On the other hand, if the air stays long enough in the grain it will have all the moisture it can pick up before reaching the last layers, and the "zone" effect will be very evident.

When evaporation of the grain moisture occurs, heat is absorbed. In such a drier as we are discussing there are only two possible sources of heat for evaporation: (1) the sensible heat in the grain and (2) the sensible heat in the air. Usually the grain is not hot enough at the start to supply much of the heat so that the air must furnish practically all of it. For this reason the air must be cooler when leaving the grain than when entering and the amount of the temperature drop in the air can be used to measure the amount of drying done. For each pound of water evaporated by 1000 lb of air, the air temperature will drop by about 4 to 5 F (degrees Fahrenheit).

If we were to follow one pound of air through a bin of drying grain, we would find that when it entered the first layer of grain some moisture would be evaporated. By the time it had picked up 0.001 lb of water, its temperature would be some 4 or 5 deg lower, its humidity of course being higher. Moisture would evaporate less rapidly in successive layers because of the lower temperature and higher humidity. Eventually its moisture content would be high enough and its temperature low enough that no more drying could occur. The total heat of the air would be the same as at the start, but some of its sensible heat would have been used to supply heat for vaporization which now is contained in the air as latent heat. This is a process of constant total heat. Since the total heat of the air is measured by the wet-bulb temperature, it is simplest to express this process as being one of constant wet-bulb temperature. In this type of drier the wet-bulb temperature of the air exhausted from the bin is equal to the wet-bulb temperature of the air entering the bin. This relation is modified if there are excessive losses of heat by conduction or radiation, or if the grain temperature is much higher or lower at the finish than at the start, but in this analysis these factors are neglected. It is also modified by the fact that grain moisture requires more heat for vaporization than does free water. In general, as the air passes through the grain, its wet-bulb temperature remains unchanged, its dry-bulb temperature drops as evaporation takes place, and its relative humidity increases.

In a bulk grain drier, the drying rate obviously varies from layer to layer and from time to time. The change in moisture content of the grain in a given layer and at a given time depends upon the character of the grain and the air

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Philadelphia, Pa., June, 1947, as a contribution of the Farm Structures Division.

WILLIAM V. HUKILL is senior agricultural engineer, division of farm buildings and rural housing, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture.

used for drying. Assume a bin of uniformly moist grain through which air of a constant initial quality and volume is to be blown. The air will be introduced through a perforated floor and move upward through the grain which is of a uniform depth. The following factors combine to determine the moisture content at a given layer (say, the top layer) at a certain time after the air flow has started:

1 The initial grain moisture content
2 The initial grain temperature
3 The drying rate at full exposure for the kind of grain
4 The relation between grain moisture and air humidity at equilibrium
5 Latent heat of drying of the moisture in the grain
6 The depth of grain through which the air passes to reach the given layer
7 The initial air temperature (dry-bulb)
8 The wet-bulb temperature of the air
9 The volume of air passed through the grain.

Grain Moisture Content. It is most convenient for this purpose to express the moisture content in per cent, dry basis. When expressed on the dry basis, a change in moisture content of 1 per cent represents the same quantity of water at all moisture levels.

Grain Temperature. If the grain is warmer or colder at the start of drying than its final temperature, it supplies or absorbs some sensible heat, thus increasing or decreasing the evaporation. For the present analysis, the effect of initial grain temperature may be neglected. However, the increased moisture content sometimes observed in the grain where the air leaves the drier is usually due to a low initial grain temperature.

Exposed Drying Rate. The drying rate for fully exposed grain is a function of the air temperature and humidity and the grain moisture content. It is affected but slightly by the air velocity. At a given temperature, humidity, and moisture content, each kind of grain dries at a characteristic rate, the smaller grains, in general, drying faster than the larger ones. The characteristic rate for each grain also varies with previous treatment. For example, sorghum which has been dried once and rewetted dries somewhat more rapidly than naturally wet sorghum. In ear corn there is a large variation in drying rate due to size of ear, tightness of kernels, etc. The characteristic drying rates have not been measured for each of the kinds of grain. In general, at a given dry-bulb temperature and humidity, the rate of moisture loss has been observed to be approximately in proportion to the difference between the moisture content of the grain and the moisture content which it would have at equilibrium with the air. At a given moisture content and at a given wet-bulb temperature, there will be a dry-bulb temperature at which the grain and air are in equilibrium. Under these conditions the rate of moisture loss at full exposure appears to be approximately in proportion to the difference between the dry-bulb temperature of the air and the dry-bulb temperature which the grain would have at equilibrium; that is, as air moves upward through grain of uniform moisture content, the wet-bulb temperature of the air remains constant but the dry-bulb temperature drops, approaching a temperature at which the air and grain are in equilibrium. At any point along its path the rate of evaporation seems to be about proportional to the amount by which the dry-bulb exceeds its final equilibrium temperature. With these two assumptions, both of which are only approximately true, it is possible to follow the course of the drying air through the grain, and compute the rate of evaporation at any level and also the moisture content at any time after drying starts.

Relation Between Humidity and Grain Moisture Content at Equilibrium. The equilibrium moisture contents for many grains have been measured by a number of observers. In general, the moisture content in equilibrium with a given relative humidity decreases as the temperature increases, but over a small range of temperature the change is small.

Latent Heat of Drying. The heat of vaporization of free water is known accurately at all ordinary temperatures and pressures. If the same amount of heat were required to evaporate moisture from grain, the steam tables would provide all the data necessary on latent heat. However, in evaporating moisture from grain, a quantity of heat in addition to the heat of vaporization of free water is required. The amount of heat used in vaporization varies with the moisture content and no doubt with the character of the grain, although there are few data available on this point.

Depth of Grain. The depth of grain through which the air passes, together with the velocity of the air, determines how long each particle of air stays in the grain. In general, the longer the air takes in passing through the grain, the more completely the available sensible heat in the air is used for evaporation and the more the difference in drying rate between top and bottom layers.

Air Temperature. Raising the temperature results in shortening the time required for drying.

Wet-Bulb Temperature. Since drying takes place at nearly constant wet-bulb temperature, the maximum total heat available from the air is the sensible heat represented by a drop in temperature from the initial dry-bulb to the wet-bulb. At moisture contents below 30 to 40 per cent, dry basis, even less heat is available because the dry-bulb cannot drop to equal the wet-bulb temperature unless the air is exhausted from the grain at 100 per cent relative humidity. The initial dry-bulb and wet-bulb temperatures in combination determine the relative humidity and the final moisture content which the grain approaches.

Volume of Air. As air of a given condition is introduced into the grain, the rate of drying of the very first grain with which it comes in contact is influenced very little by the rate of air supply. It dries at the rate characteristic of the grain for fully exposed conditions. As the air passes on to successive layers, its moisture content increases and the temperature drops, the amount of this change depending upon the rate at which air is supplied. If the air is supplied in large volume, its condition changes proportionately less in passing through a given thickness of grain than if supplied in small volume. Tests indicate that under conditions of given initial temperature, humidity, and grain moisture content, the factors of depth of grain and rate of air flow in cubic feet per minute per square foot of floor area may be combined into a single factor of pounds of air per minute per unit weight of dry grain and handled independently of grain depth or air velocity. For example, if air is passed through grain at the rate of 1 lb per min per 100 lb of dry grain, the moisture changes in the bottom layer, in the top layer, and in intermediate layers will be the same whether the grain is in a deep column of small cross section or in a shallow depth of large cross section.

In heating air for grain drying the amount of heat supplied to the air by the heater appears directly as sensible heat in the air. The amount of heat required is the product of the number of pounds of air, the temperature rise in degrees Fahrenheit and the specific heat of the air. The specific heat at constant pressure may be figured at 0.24 Btu per lb per deg. The amount of heat in the air available for drying when the grain has a moisture content in excess of roughly 40 per cent, dry basis, is the product of the number of pounds of air, the specific heat of air (0.24), and the temperature difference between the dry-bulb of the entering air and the wet-bulb. That is, even under conditions where the air leaves the grain in equilibrium with the wet grain, the maximum amount of heat available for drying in each pound of air is the initial dry-bulb minus the initial wet-bulb times the specific heat. The maximum theoretical coefficient of availability of heat in the drying process is the heat available for drying divided by the heat supplied. This equals $(D_2 - W_2)/(D_2 - D_1)$, where D_1 = dry bulb before heating, D_2 = dry bulb after heating, and W_2 = wet bulb after heating. This is the maximum theoretical coefficient, not considering the radiation losses from the drying bin. It will be noted that it may exceed 100 per cent in the case where W_2 is less than D_1. This may be so when the atmospheric air has a low relative humidity. In this case, the air can leave the grain at a temperature lower than atmospheric and the atmosphere thus supplies some of the heat for vaporization. If the initial moisture content of the grain is below 30 to 40 per cent (dry basis), it is in equilibrium with

air at a humidity lower than 100 per cent. For this reason, the drying air cannot be reduced in temperature down to the wet-bulb temperature, W_2, but will eventually reach a temperature somewhat above W_2, at which no further evaporation can take place. This temperature may be found on the psychrometric chart by reading the dry-bulb temperature at the point where the initial wet-bulb temperature of the air intersects the relative humidity corresponding to the initial moisture content of the grain. This temperature may be called W_g, the temperature at which air exhausts from grain after having come to equilibrium with it.

For very wet grain, $W_g = W_2$. In general, for grain of any moisture content the maximum possible coefficient of availability of heat becomes $(D_2 - W_g)/(D_2 - D_1)$. This represents the performance which can be attained (neglecting radiation losses) in a continuous drier or one in which the air is discharged at all times in equilibrium with the wet grain. In a batch drier, such as we are discussing, the air may leave the grain in such equilibrium during the early stages, but as drying nears completion the air comes off less and less saturated, the discharge air temperature rises, and less and less of the theoretically available heat is used. This brings in an efficiency factor, which depends on how much the average exhaust temperature over the whole drying period lacks of being as low as the theoretical exhaust temperature, W_g. Obviously, if air is put through at a rate fast enough that it leaves the grain without picking up its theoretical maximum of moisture throughout the drying period, the efficiency will be lower than if there is only a short time near the end of the drying period when it leaves the grain relatively unsaturated. In this type of drier there must be a time near the end of the drying period when some of the theoretically available heat in the air is not used because there is no longer any grain having as much moisture as at the start. The amount by which the drying process fails to use all the available heat depends upon the relation between the amount of grain, the volume of air, and the exposed drying rate of the grain.

As mentioned previously, tests of exposed drying rate showed that for each kind of grain exposed to air of a given wet-bulb temperature, the drying rate (1) is independent of air velocity; (2) at a given relative humidity it is proportional to the difference between the grain moisture content and the equilibrium moisture content (expressed on the dry basis), and (3) at a given grain moisture content it is proportional to the difference between the dry-bulb temperature of the air and the dry-bulb temperature of air in equilibrium with the grain.

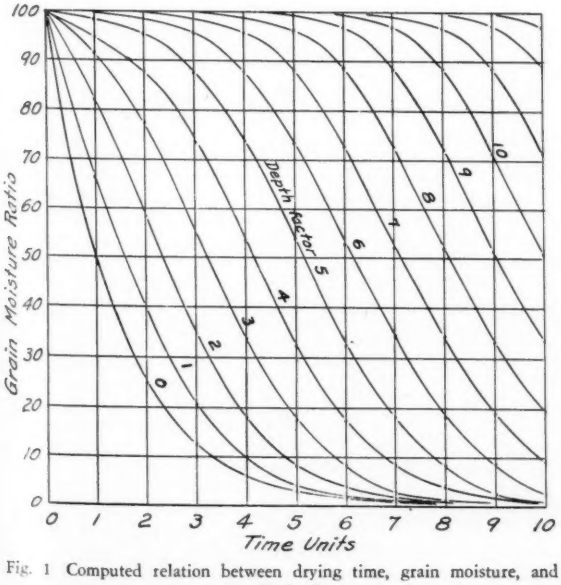

Fig. 1 Computed relation between drying time, grain moisture, and grain depth

Each of these assumptions is only approximately true and engineering of grain drying will not be complete until accurate expressions for these relations are worked out. However, on the basis of these assumptions, bulk-drying rates can be computed because they form a basis for calculating the change in moisture content of the grain as air passes through it and for computing the change in moisture content and temperature of the air as it passes through the grain.

Using these assumptions and using observed exposed drying rates, typical bulk-drying rates were computed. Later bulk-drying tests, which are still in progress, were made to measure the accuracy of these assumptions. The computations of bulk-drying rates were made as follows:

Taking a grain such as ear corn at an initial moisture content of 50 per cent (dry basis), wet-bulb temperature of the air of 71.2 F, and a dry-bulb of 108.8 F (relative humidity, 15 per cent), for example, exposed drying rate studies show that exposed ears under these conditions dry at a rate of 1.6 per cent per hour. As the corn dries the drying rate is slower, finally reaching equilibrium with the air at about 6 per cent. If 100 lb of air per minute is moved upward through a layer of this corn, containing, say, 100 lb of dry matter plus 50 lb of water (50 per cent dry basis), moisture is given off from the corn at the rate of $100 \times 0.016/60 = 0.027$ lb per min. The 100 lb of air is picking up this vapor, and as it leaves the corn, it will have gained (0.027/100) 0.00027 lb of vapor per pound of air. It will have dropped in temperature a little over one degree. (This is observed by following the constant wet-bulb line on the psychrometric chart.) It now enters a second layer of corn, but is cooler and contains more moisture, so the second 100 lb of corn will give off less moisture. This quantity can be determined on the assumption that at a given moisture content the drying rate is proportional to the difference between the dry-bulb and the temperature described as W_g which in the case of corn with 50 per cent moisture is substantially equal to the wet-bulb temperature. By determining the drying rate in the second layer of corn, the temperature drop in the air as it passes through the second layer may be computed. This process may be followed through any desired number of successive layers. Eventually the air becomes saturated if there are enough layers of corn.

The moisture content of each layer of corn at successive time intervals can be determined similarly. These computations were made graphically for a number of different conditions of temperature, humidity, and grain moisture, and all resulted in a set of drying curves which could be reduced to a common form. Fig. 1 shows this computed family of drying curves. The ordinate is a moisture content ratio; that is, the range from equilibrium moisture to initial moisture content (dry basis) is shown on a scale of 0 to 100, so that the moisture scale may be made to represent any combination of initial and final moisture, 0 being the equilibrium moisture content and 100 being the initial moisture. For example, in the case of the ear corn just mentioned, 6 per cent would be plotted as zero and 50 per cent as 100. The abscissas are time units, the length of the unit in hours being equal to the time required for fully exposed grain to reach halfway to equilibrium for any given set of drying conditions. The curves represent the moisture content of successive layers of grain in a bulk drier. The curve marked "0" represents the moisture content of the bottom layer and is the same as the drying curve for fully exposed grain under the same conditions. The lines, 1, 2, etc., show the moisture content of layers of grain at successive depth increments. The depth unit for a given set of conditions depends upon the number of pounds of grain (dry weight) traversed by the air. The number of pounds of grain contained in each depth unit is

$$G = \frac{Q \times 60 \times \Delta T \times S_A \times H}{0.01 \times \Delta M \times V}$$

in which,

G = pounds of dry matter in a layer of corn one unit deep

Q = volume of air in pounds per minute

ΔT = the maximum temperature drop that may occur in the air = $D_2 - W_g$

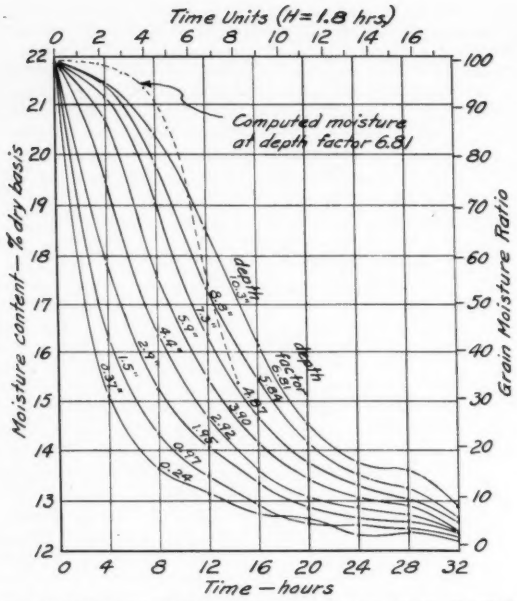

Fig. 2 Moisture content of sorghum grain during drying. Total depth of grain, 11.0 in; air supplied, 19.6 cfm per sq ft at 86.5 F dry bulb, 69.6 F wet bulb

S_A = specific heat of air at constant pressure which may be taken as 0.24 Btu per pound degree

H = the time in hours required for fully exposed grain to reach halfway to its equilibrium moisture

ΔM = the total possible change in moisture content of the grain = initial moisture minus equilibrium moisture (per cent dry basis)

V = latent heat of drying, Btu per pound of water.

This expression defines the depth unit as containing enough grain that, if all the theoretically available heat could be used, it would all dry to equilibrium in the time taken to dry fully exposed grain halfway to equilibrium. That is, the numerator expresses the total heat available in one unit of time (H hr); and the denominator, the heat required to dry one pound of grain (dry weight) from its initial moisture to equilibrium moisture.

Fig. 1, with general units of moisture content, time, and depth of grain, permits conversion of specific conditions to general units and reading the moisture content at any point in a bin at any time after drying starts. Since the assumptions on which it is based are only approximately true, tests are being made with ear corn and grain sorghum to determine what modifications in the form of the curves or the method of computation are necessary to make the chart fit the actual drying process.

In the drying tests it became apparent that the chart (Fig. 1) underestimated the time required for drying when the value of heat of vaporization was taken from tables for free water. There is very little available information on the heat required to evaporate water from grain. Clausius equation[1] shows that it is a function of the change in vapor pressure with respect to temperature, but precise data on vapor pressure at various temperatures and moisture contents of grains are also lacking. In order to get a basis for estimating the latent heat required for evaporating grain moisture, the heat released when grain sorghum is wetted with liquid water was measured. This was done in grain having an initial moisture content of about 10 per cent (dry basis) and a final moisture of about 16 per cent. The tests will not be described here, but in this range of moisture content the heat of wetting was measured at about 120 Btu per lb of water. It was assumed that when evaporation occurs the heat of wetting must be resupplied in addition to the normal heat of vaporization of free water. The heat of vaporization of free water at 75 F is about 1050 Btu per lb, so the heat required to evaporate water from grain is taken at 1050 + 120 = 1170 Btu per lb of water. This figure actually varies with temperature and moisture content, but more information on the amount of heat required by the various grains at various moisture contents is needed. In the absence of further data the tests were computed on the basis of V = 1170 Btu per lb.

Fig. 2 shows the moisture content at various levels in one of the tests on grain sorghum. In this test 189.5 lb of sorghum having an average moisture content of 21.9 per cent (dry basis) was dried. The grain had been dried previously and was rewetted for the test. The average entering air, dry-bulb temperature, was 86.5 F and the wet-bulb, 69.6 F. Seven pounds of air per minute was passed through the grain. The equilibrium humidity of the wet grain was about 85 per cent, giving a temperature, W_g, the theoretical temperature at which the air would leave the grain at equilibrium, of about 73.0 F. The equilibrium moisture content of sorghum corresponding to the condition of the entering air was about 12.1 per cent, dry basis. Moisture content of grain samples from eight different levels were taken every four hours but it was estimated that the grain where the air entered dried halfway to equilibrium in 1.8 hr.

With these data the depth factor for the grain in the test may be computed. The amount of grain in one depth unit is

$$G = \frac{Q \times 60 \times \Delta T \times S_A \times H}{0.01 \times \Delta M \times V}$$

For the conditions of this test

Q = 7.0 lb per min
ΔT = 86.5 − 73.0 = 13.5 F
S_A = 0.24 Btu per lb deg
H = 1.8 hr
ΔM = 21.9 − 12.1 = 9.8 per cent
V = 1170 Btu per lb

so that $G = (7.0 \times 60 \times 13.5 \times .24 \times 1.8) / (0.01 \times 9.8 \times 1170) = 21.3$ lb of dry grain. The total amount of wet grain in the bin was 189.5 lb containing 21.9 per cent moisture, or 155.4 lb of dry grain. The depth factor for the whole quantity of grain in this case was 155.4/21.3 = 7.3 depth units.

The computed moisture contents from Fig. 1 are shown for the top layer by a dotted line. In this test, as in each of the others, the actual drying rate was *(Continued on page 340)*

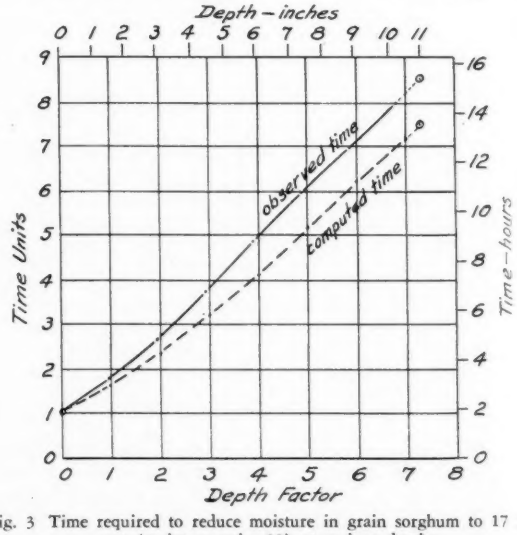

Fig. 3 Time required to reduce moisture in grain sorghum to 17 per cent (moisture ratio, 50) at various depths

[1] Clausius Equation: $H_{fg} = V_{fg} T (dP/dT)$, in which H_{fg} = the heat of vaporization in foot-pounds per pound; V_{fg} = the volume of the vapor in cubic feet per pound; T = absolute temperature, °R; and P = vapor pressure in pounds per square foot.

Chemical Weed and Plant Control

By W. C. Dutton

THIS paper will deal not only with the control of weeds, as we ordinarily think of them, but also with undesirable woody plants, the defoliation of certain crop plants and nursery stock, and the killing of potato vines. The use of chemicals for weed control is by no means new, but there has been an immense increase in interest and research in recent years. A discussion of some of these materials follows.

Soil Sterilants. Sodium chlorate, sodium arsenite, and borax are examples of materials that have long been used. They will kill any top growth by contact but their effect is largely by absorption from the soil. They sterilize the soil for some time, which is dependent upon amount used, type of soil, amount of rainfall, etc. They are widely used where no vegetation is desired and when so used are classed as "permanent soil sterilants".

Some of these, used in light applications, give temporary sterilizing effects, as do certain volatile materials such as chloropicric, carbon bisulphide, chlorinated hydrocarbons, etc. Still others decompose in the soil. Calcium cyanamid is an example of this class.

Contact Herbicides. Many chemicals have been used to kill the tops of plants by contact. Small annuals are easily killed by such treatment, but deep-rooted perennials only by repeated applications. Sodium chlorate and arsenites (at low concentrations) have been so used, and petroleum oils are effective for certain uses. Dinitrophenols and chlorinated phenols in oil are more recent developments in this class. These so-called contact herbicides are usually used where everything above ground is to be killed, but are sometimes used to kill winter annuals in established perennial crops such as alfalfa when the crop is relatively dormant and no permanent damage results from the "burning" of the exposed alfalfa. The contact sprays are used under such conditions because there are usually present some weeds rather difficult to kill. This type of material is also being developed for use in orchards and vineyards, where it is not desirable to cultivate, for keeping ground cover under control and to kill certain insects that may be harbored in the ground cover.

Selective Weed Control. The greatest and most important developments have been with the "selective" weed killers which can be used to control many weeds without killing or causing serious injury to the crop in which they are growing. Selectivity can be broadly classified in two ways: physical and physiological. Physical tolerance is usually determined by the form of growth and by the presence of waxy or other protective surface which tends to reduce deposit of toxicant or to protect against its effect. Physiological tolerance simply means that the plant is not affected seriously by a chemical when used in such amounts as needed to kill weeds.

There are several types of materials used for the selective control of weeds in crops and in turf. Sulfuric acid is used on onions and selectivity depends on physical factors. Salt can be used for weed control in garden and sugar beets. Just why beets tolerate salt sprays is not well understood. A very interesting case of what is probably physiological tolerance is with carrots, parsnips, and related plants when sprayed with certain petroleum fractions. The oil kills many weeds but without injury to the crop if properly used. Stove oil, Stoddart solvent, and other petroleum fractions are used.

Calcium cyanamid dust, under certain conditions, acts as a selective treatment for the control of weeds in flax and grain crops. The salts of some dinitrophenols have been widely used as selective sprays on flax, peas, and small grains and under arid conditions on onions. They are specially effective against mustards and related species. Some weeds are not killed but are checked so that the crop will overgrow them. Selectivity is undoubtedly due to physical factors.

The selective materials discussed in the preceding paragraphs are all important and undoubtedly will continue in use, but the most phenominal development in weed control is from the use of 2,4-D (2,4-dichlorophenoxy acetic acid) which is one of a group of chemicals generally classed as plant-growth regulators. It is used in water solution as the sodium, ammonium, and amine salts. The esters are oil soluble and are used in emulsifiable compositions. 2,4-D does not kill by "burning", as is true of many other materials, but by being absorbed and translocated to other parts of the plant. The first visible response is to cause growing parts to twist and bend; abnormal spongy tissue may develop and the susceptible parts go to pieces and die rather slowly. Small seedlings may die in seven to ten days; dandelion, plantain, etc., in ten days to three weeks depending on temperature, moisture, and rate of growth. Deep-rooted perennials may not be completely killed and regrowth will need to be treated. 2,4-D is not effective unless the plants are in active growth and its action is unquestionably physiological in nature. Selective tolerance to 2,4-D may be determined by both physical and physiological factors. Heavy, waxy protective coatings of plants are not easily penetrated by the water sprays of 2,4-D salts. The esters in oil, under such conditions, are often more effective. The most important tolerance of plants to 2,4-D, however, is physiological in nature — some plants simply are not affected by it — and there is no rhyme or reason to plant tolerances and susceptibilities. Many ordinary grasses are tolerant, but their roots are usually more susceptible than the tops. Tomatoes are highly susceptible, but some closely related species are very resistant. Grains in general are tolerant of 2,4-D in several stages, but susceptible in others. Flax is moderately tolerant, and there is some indication that it may be used safely under some conditions. Most legumes are very susceptible to its effects.

2,4-D will probably be used extensively in place of dinitro selective sprays on small grains

Left: A portion of this vegetation-filled ditch, in the distance, has been sprayed with 2.4-D • *Right:* This is a close-up of the sprayed portion of the ditch shown at the left

This paper was presented at a meeting of the Michigan Area Section of the American Society of Agricultural Engineers at East Lansing, Mich., March 1, 1947.

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that do not have legume seedings in them, and it has revolutionized weed control in many other places where no satisfactory material was previously available.

Woody Plants. The control of woody plants on power line, railroad, and highway rights of way is often a major problem. Woody plants also monopolize much pasture and grazing land, and poison ivy and honeysuckle are widespread pests. Woody plants in general are more difficult to kill than herbaceous plants and some are very resistant, but it is possible to greatly simplify the eradication of many species by the judicious use of 2,4-D.

Row Crops. Much work is in progress to develop ways of using chemical weed killers to supplement cultivation in row crops such as corn and others. Most all vegetables and flowers are highly susceptible to 2,4-D.

Defoliants. There is a strong demand for chemicals to defoliate cotton so that mechanical pickers can be used, and to defoliate soybeans so that they can be harvested with combines prior to killing by frost. Calcium cyanamid is used satisfactorily under some conditions. It is also often desirable, for several reasons, to defoliate nursery plants prematurely in the fall.

Potato Vine Killers. Potato growers spray potatoes all summer to keep them alive, and then often find it desirable to spray them to kill the vines. The control of the size and type of tubers, checking the spread of virus diseases and late blight, "ripening" the tubers and causing them to loosen from the plants and eliminating clogging of mechanical diggers and harvesters are some of the reasons why vine killers are used. Many materials are available for this purpose but dinitrophenol sprays are widely used at this time.

Chemicals and Equipment. Many chemical and mechanical developments are mutually dependent on each other. In some instances mechanical developments call for a chemical to make their use feasible. Examples are cotton pickers, potato harvesters, soybean combines, etc. In other cases a chemical development creates a demand for equipment. Examples are soil fumigation and weed control. One big need now in weed control work is good equipment for applying chemicals in small amounts of water or other carrier. In other cases their use may be a problem which demands equipment and/or chemicals such as blocking and thinning of sugar beets. These are but a few examples that show the need for cooperation between those interested in agricultural chemicals and the designers and builders of mechanical equipment.

Drying Corn and Grain Sorghum

(Continued from page 338)

slower than the computed, except early in the drying period, even though allowance was made for higher latent heat. This indicates that the assumptions given earlier relative to exposed drying rate need to be modified or the latent heat required is higher than that assumed, or some of the test measurements are inaccurate, such as the rate of air flow.

Both the computed drying curves and the curves from the tests show that at a depth factor of one unit, that is, when the air has passed through one depth unit, or G pounds of grain, only part of the available heat in the air has been used; at two units, or when the air has passed through 2 G pounds of grain, a higher proportion; and as the depth factor increases, the utilization of heat approaches a constant. Data from Fig. 2 may be replotted as in Fig. 3 to show how long it takes the grain in each successive layer to reach a moisture content halfway to equilibrium. This could be represented for any other fraction of the total moisture change, but the halfway point is arbitrarily chosen to illustrate the utilization of heat by various depths of grain. In Fig. 3 the time required to reach the selected moisture is plotted against the depth factor in the grain sorghum test (Fig. 2). Similar data is also plotted from the computed moisture curves (Fig. 1). Since the heat is supplied at a uniform rate, the number of hours of operation is directly proportional to the total amount of heat supplied. Also, since each successive unit of depth is equal, the amount of grain dried is proportional to the depth factor. For this reason the ratio of the number of hours required to reach the given moisture content to the depth factor or number of depth units is proportional to the amount of heat supplied per pound of grain dried. It is noted that at a depth of one unit in the test data this ratio is about 0.167; at a depth of two units it is 0.124. As the number of depth units increases, the ratio decreases, but beyond a depth factor of 3 or 4 units the decrease in heat required per pound of grain is very small. The situation for the computed curve is similar although not identical. In either case it is clear that as the depth increases the thermal efficiency increases, but after a depth of 3 or 4 units the improvement is small. In this regard it can be said that in such a drier as we are discussing the depth factor should be not less than 3 or 4 depth units for good thermal efficiency. This can be interpreted to mean that in this type of drier the heat economy will decrease rapidly if the whole bin of grain is to be dried in less than 3 or 4 times as long as it takes to dry fully exposed grain one-half way to its equilibrium. On the other hand, there is not a great gain in efficiency if the drying is extended over a period longer than 3 or 4 times this much.

This analysis has not been checked over the entire range of moistures and temperatures encountered in grain drying. It is only approximately correct for computing the moisture contents observed in the tests so far. In the analysis presented the effect of initial grain temperature has been neglected. In general, if the grain is cold at the start, drying will be delayed and the upper layers may at first increase in moisture content. If the grain is hot at the start, drying will be faster. Before the analysis is complete for grain drying in general, the drying constants for each grain, the laws showing accurately how the exposed drying rate is influenced by moisture content, temperature, and humidity, and the heat of drying for different grains at various moisture contents and temperatures, need to be determined and reduced to a form for ready reference.

It is hoped that further tests will indicate what modifications in assumptions are required to give a more accurate representation of the general relation between moisture content, time, and depth of grain. Some such analysis by which the effects of changing conditions can be anticipated is necessary before driers can be designed and operated with full knowledge of how they will perform.

In summarizing the results of this study, the following statements appear to be justified:

1 The maximum heat available for drying is the sensible heat of the air between its initial dry-bulb temperature and the dry-bulb temperature corresponding to the wet-bulb of the entering air at the equilibrium relative humidity of the wet grain. This latter temperature may be read from a psychrometric chart and is always higher than or equal to the initial wet-bulb temperature.

2 The heat of drying of moisture in grain is substantially higher than the heat of vaporization of free water. One test showed that grain moisture required 120 Btu per lb more than free water. Further data on heat of drying are needed.

3 Drying rates in bulk can be computed from exposed drying rates with the proper drying constants and seem to be reducible to a general form for covering drying under wide ranges of grain depth, moisture content, air volume, temperature, and humidity.

4 Efficiency of bulk drying decreases rapidly as the total drying time is reduced below about 3 or 4 times the period required at full exposure to reduce the moisture content halfway to equilibrium under similar conditions.

5 When artificial heat is used, drying is generally more economical at high temperatures than at low ones. This effect appears in two ways. First, as heat is added to saturated air, the ratio of the increase in wet-bulb depression to the rise in dry-bulb temperature becomes larger as more heat is added. That is, the ratio of available heat to heat supplied becomes larger. If the atmospheric air is less than saturated, there is some free available heat in the atmosphere which may change this relation. Second, as the temperature rises the time required for a drop in moisture to the halfway point is lessened and the drying period may be shortened without losing efficiency.

Weed Control with 2,4-D

By Harold T. Barr and Clair A. Brown
MEMBER A.S.A.E.

IT HAS been estimated that the loss from weeds in the United States amounts to some $3,000,000 annually and exceeds the combined loss suffered by the farmers from livestock diseases, plant diseases, and insect pests. Weeds rob the crops of light, water, and plant nutrients, in addition to the added expense of cultivating, flaming, chopping, or spraying for their control.

Weed control investigations were started by the Louisiana Agricultural Experiment Station in the fall of 1944. The original work was for a study of the plant history and eradication of alligator weed (*Alternanthera philoxeroides*).

Alligator weed, which normally grows in waterways, has invaded the crop lands and is a serious pest in the sugar cane, rice, and truck crop areas of Louisiana. The plant has fleshy roots penetrating deep into the soil, and above ground the stems are made up of nodes and internodes. Each node is capable of producing roots and stems; thus it is easily spread by farm machinery, birds, sticking to laborers' feet, and water. To date no seed of this plant has been found in Louisiana. This plant has been reported from Texas to Florida and up the Atlantic Coast in the Carolinas.

In 1945 work consisted of mechanical methods of mowing at frequent intervals, fallow plowing, blanket burning, disking, field cultivating, and blanket spraying of infested areas. Flame cultivators and several chemicals were tested on check areas in the sugar cane fields.

Fallow plowing at 10-day intervals will keep the pest under control but does not destroy it and the use of the land is lost. The field cultivator used at 10 to 12-day intervals for one summer lessened the alligator grass infestation and reduced a heavy Johnson grass infestation to three individual plants that showed up the following year on a plot of approximately 1½ acres.

Eight severe blanket burnings one season followed by twelve the next eliminated all weeds and grasses on one plot; but there was almost a perfect stand the following year of coco grass and alligator weed.

After exhaustive tests of some thirty different chemicals it was found that 2,4-Dichlorophenoxy acetic acid, commonly called 2,4-D, gave the best results. Today there are over fifty brands of 2,4-D on the market in at least ten different formulas. In general, the various 2,4-D compounds are effective in killing the broad leaf plants and weeds, but do not injure the true grasses. This selective or differential killing makes it possible to blanket spray sugar cane and rice fields. By use of shielded sprays, tests are to be made during the 1947 crop season on cotton and corn. The killing ability of the various derivatives of 2,4-D makes it possible not only to control weeds in fields but also to bring back into cultivation much valuable land that has been abandoned.

The results of 1945 were so promising that a standard high-clearance, row-crop sprayer was purchased for large-scale test work. The boom was arranged for spraying three rows of sugar cane. Approximately 60 acres of sugar cane were sprayed with dilute sprays of 2,4-D, and 15 acres of sugar cane were dusted in 1946 tests. Several plantations, because of pressing weed problems and shortage of labor, did not wait to observe results of our acreage tests, but bought sprayers and sprayed some 3000 acres of sugar cane in 1946 with satisfactory results. Early season small plot tests on rice were so encouraging that approximately 3000 acres of rice were dusted in Louisiana in 1946.

In 1947 it has been impossible to get an accurate acreage check on the use of 2,4-D, but surveys show that about half of the sugar cane area and about half of the rice area in Louisiana are either being sprayed or dusted. In addition, large areas in drainage ditches, lakes, pastures, oat fields, and roadways have been treated with 2,4-D.

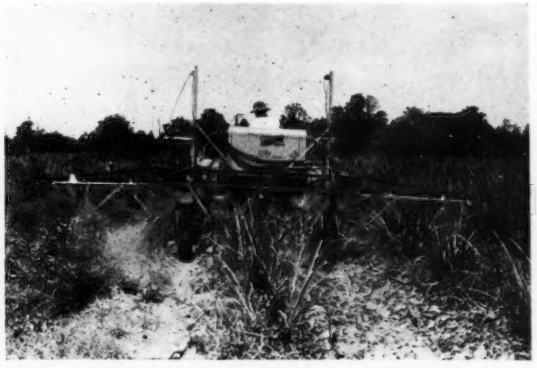
The sugar cane field test plots were sprayed with concentrations of 1000 and 2000 ppm (parts per million) and applied at the rate of 100 gal per acre. The 2000 ppm as used above gave the best control. The 2000 ppm is equivalent to 2 lb of 80 per cent, or 2½ lb of a 70 per cent formulation per acre. Smaller test plots were treated with concentrations of 10, 100, 500, 1000, 2000, and 5000 ppm.

The alligator weed shows a slight wilting within a few hours and almost complete disintegration within 3 to 4 weeks. Practical control is thus possible by one application per season. Active growing plants or seedlings are much more susceptible to the killing action of 2,4-D than dormant or mature plants. Some slight injury was noted where concentrations of 5000 ppm was sprayed on 18-in sugar cane. Some slight abnormal growth was also found where the cane was sprayed with 2,4-D esters four days after flame cultivation. Treated plots gave increased yields varying from 1.9 to 4.1 tons of sugar cane per acre with no depressing effect upon sugar content of cane.

Pressures of 200 lb and above are not desirable for spraying herbicides. The high pressures tend to mat vegetation and atomize the spray so fine that light winds cause too much drift. Pressures of 75 to 100 lb gave best results with the speed of machine and number and size of nozzle being adjusted to give the desired quantity per acre.

Where dilute sprays are to be used nearly all of the commercial spray machines can be adjusted to apply 2,4-D. Dilute sprays of 100 gal per acre can be applied in 10 to 12 min and then require 30 to 45 min to refill and get back in the field. More time is spent going to and from the field and refilling than in spraying. The 100-gal or larger spray rigs are heavy and often difficult to handle in soft damp fields. To get away from the lost time and heavy machines, 2,4-D dust was used and found just as effective as sprays of similar active ingredients. A small tractor with power duster can cover 10 to 20 acres per hour. Airplane dusting can cover 100 acres per hour. Drift from dust must be watched as it has been observed from ½ to 1 mile away from the desired plot.

Applications of 2,4-D in rice fields has controlled indigo, Mexican weed, curly indigo, and a number of other weeds. Rice in the seedling stage may be damaged by too strong a 2,4-D compound and should not be dusted at heading time. For rice, 10 lb of 10 per cent dust per acre one to three days prior to flooding is recommended. After flooding and maximum emergence of weeds, 10 to 15 lb of 10 per cent dust is recommended.



This picture shows equipment for spraying 2,4-D on sugar cane fields (June, 1946) badly infested with alligator weed

This paper was presented at the annual meeting of the American Society of Agricultural Engineers, at Philadelphia, Pa., June, 1947, as a contribution of the Power and Machinery Division.

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In some areas oat fields have become seriously infested with dock. This infestation is blamed on the use of combines which spread the weed seed, where formerly, with the thresher, the weed seed were blown into the strawstack and burned. Several test plots in oat fields were dusted in Louisiana with 2,4-D this spring and considerable oat acreage was airplane dusted in Mississippi. The dock dusted in the spring of 1947 in oat fields was stunted back in varying degrees, but regrew and was not considered controlled. However, additional applications are being made on dock at various stages of growth and in various concentrations of 2,4-D. Some sections of the south have practiced growing oats with vetch or Singletary pea, thus getting two crops off of the same land at the same time. However, some good oat crops have been lost waiting for the vetch or peas to mature sufficiently for combining. Several oat fields were dusted this spring to eliminate the vetch and peas where the owners were desirous of getting the oats for seed.

Johnson grass does not seem to be affected by 2,4-D where it is established. However, some preliminary work has indicated the possibility of killing the Johnson grass seed and small seedlings. One spraying in the fall and one spraying in March in Louisiana has proven the best method to date. In this work 4 lb of the 2,4-D sodium salt was used per acre.

Sugar cane in some areas is dusted for borer control by an application of cryolite for borer. An experimental dusting combining cryolite and 2,4-D with a talc carrier was applied during the 1946 season with no detrimental effect from combining the two.

There has been only a short period of time in which to test out the various 2,4-D compounds on many plants. In small scale tests, the following plants were readily killed with 2,4-D compounds: Carpet grass, Cherokee rose, Chickasaw rose, bat wing or turtle back, giant ragweed, indigo, lesser ragweed, milkweed, or poinsettia, mule-ear, pennywort or dollar grass, peppervine, pigweeds, poison ivy, redweed, rough-leaved marshelder, tievine, toothcups, yaupon, yellow sedge, and willow.

Erratic results in per cent of kill, injury, and sometimes regrowth, were obtained with the following group: African daisy, blackberry, Chickasaw plum sprouts, cordate-leaved pepper vine, creeping spurge, crowfoot or goose grass, curly dock, eclipta, elephant ear, elderberry, false garlic, goatweed, goldenrod, gymnostyles, horse nettles, Japanese honeysuckle, Maypop, mazus, Mexican weed, nightshade, partridge pea, primrose jasmine, roughleaf dogwood, silvery or curly indigo, smartweed, spiny thistle, teaweed, tung oil tree, verbena, water hyacinth, wax myrtle, wild onion, winged loosestrife, and Yankee weed.

It is interesting to note that many of the more serious farm pests can be controlled. Coco grass, rice weeds, cocklebur, ragweed, pigweeds, poison ivy, rose briars, blackberry briars, and dodder are found in the group easily killed.

Crop plants sensitive to 2,4-D are cotton, sweet potatoes, okra, tomatoes, peas, beans, and many ornamentals.

The compound is very difficult to remove from dusting or spraying equipment. It would be much better to have separate equipment for other spraying.

In order to get away from the heavy equipment, time lost in refilling for dilute sprays, and danger of dust drifting, concentrated sprays are to be tested in 1947 at the rates of 3 to 10 gal per acre. Some reports have been made of concentrate sprays being applied at rates as low as 1 gal per acre by airplane.

It has been found this season that some of the experimental dusts shipped to us are ground too fine and increases the drift hazard on still days.

A high velocity dust machine allowed 8 acres to be covered in 16 min, but it was found impossible to get a uniform kill of weeds in areas where this machine was used. Row-crop dusters equipped with nozzles fairly close to the ground have proven best in sugar cane fields.

Airplane dusting is satisfactory for large areas. However, a word of warning on airplane dusting should be sounded here. A recent dusting by airplane of an extensive waterway and connecting lake resulted in the killing of several hundred acres of cotton, corn, beans, gardens, and trees. An additional cotton acreage was killed where a pilot had used his plane for dusting rice with 2,4-D and then switched to dust for cotton boll weevil. It may be necessary for states to pass some laws governing the use of various dusts and also the practices that some pilots have of cleaning their tanks by going up to high altitudes, opening tanks and diving to clean out the remaining dust.

Storage and containers for 2,4-D should be carefully considered. In one small town used for a distribution point, the dust was stored in factory-filled paper bags in a frame garage. All of the gardens and shrubbery for 600 ft in three directions and 1200 ft in the fourth direction are showing peculiar abnormal growth and some dying. The symptoms are the same as areas where 2,4-D had been applied.

The chemicals can be used to control weeds at a very reasonable price and will become increasingly more important as more research results become available.

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Left: The left-hand row (of sugar cane) in the foreground of this picture was sprayed with 2,4-D during the 1945 season, but the right-hand row was not sprayed. The picture was taken in 1946, ten months after spraying • *Right:* This picture shows a checkrow (right) and a sprayed row (left) of sugar cane, one month after spraying with 2,4-D

Coordinating Research and Development of Joint Interest to Agriculture and Industry

By H. A. Lyon

AGRICULTURE is, in at least one phase, the business of all of you, and you accept as natural the need for accomplishments in the field of agriculture, our largest basic industry. Unfortunately a great number of industrialists and merchants, including many of those who deal directly with farmers, do not appear to consider that they have the slightest responsibility to agriculture, beyond trying to sell the farmers their products or to purchase what the farmer has to offer.

It is that condition which makes our Detroit Agricultural-Industrial Foundation a novelty. Started a little over two years ago, under the inspiration of Roger M. Kyes of Harry Ferguson, Inc., some 140 industrialists, merchants, bankers, professional people, educators, and others have been conducting an active program looking toward some contribution to agricultural progress.

The reasoning of this group is a little unusual, but by no means abstruse. We know that agriculture is a basic industry. So far as concerns our food, clothing, shelter, and fuel it is not merely a matter of our acquiring these in sufficient quantity and quality to exist; the cost of production and distribution of these goods has a tremendous effect upon the largest single cost in industry and business—wages and salaries. Historically, labor has tied its demands for wage increases to cost of living. Never has that been better illustrated than today. Costs of labor must inevitably be translated into final production costs for industrial goods, and unless we can produce and distribute at lower and lower costs, the volume of distribution and the number of those who would enjoy what is produced must diminish. Beyond that, however, we realize that the amount of purchasing power which is left over among city workers after they have bought life's necessities, will have a considerable bearing on the volume which they can afford of the other goods which industry produces. The importance of this condition to business is clear.

Raw materials constitute the second largest cost in final industrial production. We appreciate that about two-thirds of all of our industrial raw materials now come from the farm; and again, if we are to produce and distribute to more people, we must see what can be done toward getting the costs of these contributing factors down, without reducing farm income.

The volume of city purchasing power is no more important per capita than the volume of rural purchasing power. Traditionally, rural purchasing power has been below that of city dwellers, except during very brief intervals, such as wars, in the past several decades. The rural market of this country in villages and on farms, numbering about 55,000,000 people, are known to be consumers of just about every type of goods which we can produce, and it is of extreme importance in the maintenance of our production schedules, in continuing employment, and in the preservation of a reasonably stable volume of business, that adequate purchasing power should be available to the rural groups.

There is not much need to elaborate on the migration of rural youth to our cities, nor do we need particularly to stress the fact that no city of 25,000 people or more in this country is today replenishing its own population. The problem is a dual one of attracting enough efficient young people to farm life so that farm production may continue, and at the same time furnishing a fine type of citizenry for our future city populations. Clearly both of these are of direct concern to business.

It is to the selfish advantage of business and industry not only to recognize these truths but actually to do something about them, in our own interest. There are many things which business can do to improve its own position, based upon improved agricultural conditions. The number of things which city people can do can be measured quite accurately by examining the extent of responsibility of these groups for factors which affect agricultural prosperity and which are practically the sole responsibility of city people.

But before I start to discuss our specific activities let me say that the basis of many of them lies in thoroughgoing cooperation with Michigan State College and other educational institutions, first in discussing those things which we might be doing, and second in doing them. We make no pretense of accomplishment solely by ourselves.

You will be interested in our research committee. This committee is made up of top-flight men from major local industries, such as Chrysler Corp., Detroit Edison Co., Dow Chemical Co., General Motors, Ford, Parke-Davis, Harry Ferguson, U. S. Rubber, Great Lakes Steel Corp., and representatives of the Michigan State College, Wayne University, and others. It may fairly be expected to represent some of the best industrial research brains in the country, at least along certain lines. Many of them are of the same group that started the Inventors' Council during the war.

One of the first and perhaps the most dramatic suggestion received by this committee was posed by the authorities of Michigan State College. The proposal was something like this: The State of Michigan, like a good many other states, suffers a considerable damage annually to its various crops from frost. During the war engineers devised smoke and fog screens which could be spread quickly from the air and which would cling for a considerable time to the surface of the ocean or the land to conceal troop and ship movements. Do you suppose you could carry your ingenuity a little further and devise a somewhat similar process by which we could spread screens over orchards and crops as a protection against frost? I think the attitude of the group was expressed, perhaps best, by C. F. Kettering. He said, "We did cooperate during the war on a great many different things for the protection and defense of our country. I see no reason why we should not continue our efforts during peacetime with a similar end in view, and I can think of no better field in which to cooperate than in agriculture."

The question as originally stated has, up to the moment, received no direct answer of practical value. However, a lot of experiments were undertaken at Michigan State College, and many of them with our cooperation. We have provided materials, laboratory and engineering work, and a lot of productive contacts.

We believe that a solution has been found, one which is practical, effective, and should be made available to farmers at a price which almost insures a profit through its use.

None of those industrial companies, which have made contributions to this study, expect to make a single dime directly out of their contribution. They will be entirely satisfied if a device can be furnished to the farmer which will be profitable for him to use. The second point is this: Before we started this program, if farm losses due to frost were called to our attention at all, we probably merely expressed perfunctory regret for the farmer. Now our attitude is: If Michigan farmers suffer a $20,000,000 loss from frost damage, they will not have that $20,000,000 worth of purchasing power to buy what we make. We, in turn, will not be able to hire the men to produce that amount of goods, we shall not have the factory payroll for that production, the local merchants will not have that amount of trade, and the whole economy will suffer. Actually, it appears probable that we are no longer talking about a $20,000,000 loss to the farmer, but a loss of

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H. A. LYON is director of the Detroit Agricultural-Industrial Foundation.

$140,000,000 to $150,000,000 to the whole economy, of which industry and commerce bear the largest burden. I think that you will be particularly interested in this piece of philosophy, since it represents a healthy change in industrial thinking, and a necessary one.

I have told you that we prefer to cooperate with agencies like Michigan State College in selecting projects for our work. By this I imply that we do not go directly to the farmers, but rather to their representatives who should be able to speak knowingly of the farmers' problems. But I should like to say that some projects may, and one project has, originated within our industrial group in which we are seeking the active participation of the State College. This has to do with the application of industrial management and organizational techniques to agriculture. The approach by mass production industry, of which Detroit is an excellent example, to problems of production is usually the engineering approach. Consequently that is the natural approach of the individual members of our research committee to a variety of agricultural problems. We have been beset by requests from individual farmers and farm groups throughout the country to undertake this or that sort of research, each, in the opinion of its proposer, representative of the thing the farmer needs most. But we, as a group, are forced to seek those items which promise the optimum in time and labor saving, and in profit making for the farmer. So we have asked the College from time to time to tell us what, in their opinion, the farmer does need most, and what would be most profitable in the field of development. Our point of view is simply that we prefer to use our time and talents to the greatest probable advantage. I think it is not any fault of the College that we have not been able to get precise answers at all times to such questions.

We have, therefore, urged the College to find out the answers which will permit us to be most effective. And we are offering the cooperation of industrial efficiency men. Quite obviously, this involves a study of what it is that takes the bulk of the farmers' time, because that reveals the areas where time saving would be of the greatest importance, and therefore bring the highest profit. We believe that we can be of assistance in such studies. We did find out that a large bulk of the so-called time and motion studies heretofore made by land-grant colleges have stressed the efficiency of manual operations. I refer in particular to a number of studies carried on during the war under a grant from the General Education Fund, and in some instances to work carried on since that time by the individual colleges. I do not want anything I say to be construed as a criticism of this effort. However, studies of this sort, carried on usually by the economics staff, differ from the usual industrial or engineering approach, and therefore do not much further our particular purpose.

GOAL IS REDUCTION OF PRODUCTION COSTS

Please recall that our goal, in condensed terms, is to help achieve a reduction in the cost of production and distribution of cost of living items and industrial raw materials while, at the same time, increasing farm and rural purchasing power. We know of only one set of circumstances which will permit this, the application of efficiency techniques to production work on the farm (and in distribution), with the savings, as in industry, to be shared between the producer and the consumer. We have now allied ourselves in such a study with representatives of several departments of the College, to endeavor to devise work-flow charts for one or more individual operations to be naturally encountered in one type of farming. Actually the pilot upon which we are concentrating is the apparently simple operation of getting milk from the cow to the cooling room. Probably you in your professional capacity would not be startled at the lack of agreement as to the essential activities which should be included in this simple operation and their proper order. We were. We now have that work-flow chart, at least in tentative form, to which this group of college men has agreed. We now propose to add to their knowledge the know-how and observation of a small pool of trained industrial efficiency men, with the hope that we can find in this single operation a pattern for continuing studies. Obviously, when the pattern is satisfactory to both industrial and agricultural engineering men, it will be necessary to make time studies on a number of different farms. Then the information must be correlated until we have a pattern which can be developed in almost every operation for every type of farm.

What is it that we hope may develop out of such studies? First of all, it seems to us that there is some probability of obtaining highly valuable information as to the arrangement and types of buildings, structures, and facilities. Second, we hope to discover those areas most susceptible to mechanization and with the promise of the greatest saving in farm time and labor. Third, we anticipate at this moment that it will reveal a good many things which the manufacturers of existing facilities are apparently not now telling the farmer about the capacities of their equipment.

For ourselves, we are but a small group, and Michigan State College is but one institution. If we can find the pattern which I have mentioned, which is as promising as I myself hope, we feel that it might well be possible to apportion varying types of farm studies of this same nature, and using the basic pattern, to the various land-grant colleges, each according to its prime interest. If each land-grant college will enlist the aid of businessmen in its state who can contribute what our industrialists in Michigan are trying to contribute, and if then the sum total of all of the knowledge so acquired can be distributed among all of the states, it seems to us that a considerable short cut may have been achieved.

You will notice that throughout I have hedged this statement. We are accustomed to hedge most of our statements and shall continue to do so until we arrive at demonstrated truths. Meanwhile we can only use our best judgment and participate in tests which are necessary to prove that such a study is, or is not, of practical promise. I might add, however, that the widespread collaboration of land-grant college men and industrialists throughout the country could not help but redound to the benefit of the colleges and of agriculture itself.

HOW BUSINESS CAN HELP THE COLLEGE

There is one other area in which businessmen can most certainly serve an institution like a state college. With or without our help, Michigan State College, like most other land-grant colleges, has developed and will continue to develop methods, materials, or devices which are susceptible of improving agriculture, *provided they can be materialized*. Not infrequently a college supported by public funds is in a dilemma as to the use of patents. Some, of course, feel that they should take out open patents, which all too frequently come to nothing inasmuch as the manufacturers who might otherwise be interested have no protection during the period of their own experimentation. In some other instances the colleges themselves have risked disapprobation on the part of the taxpayers and have themselves licensed the manufacturers of these items in a way to yield substantial income to the institutions. To us there is a third way, and we are already in agreement with Michigan State College on the broad principles involved. Michigan State College may turn over to our Foundation such patents or patents applied for or such methods as they wish, for commercial exploitation. Our Foundation may or may not accept these, within its judgment. However, if it does receive and accept such a request from the College, the Foundation will serve as assignee of the patents and will undertake, to the best of its ability, to obtain actual production and distribution of items of value to agriculture at prices which are as low as possible to the farmer, and at the same time reasonably profitable to the manufacturer. By this means, utilizing the knowledge and intelligence of businessmen accustomed to this sort of thing, we believe that the College can acquire funds for additional research without incurring criticism—actually, probably larger funds than might otherwise be obtained.

You are of course interested in soil conservation. So are we. It has often been said that businessmen and other members of the urban communities should interest themselves in this subject for their own good. In this particular instance, our point of view is that we are concerned with the conservation and, where possible, the restoration of *all* natural resources of our state. We feel that our work is primarily of an educational nature, and that we, perhaps better than anyone else, are in a position to examine *(Continued on page 346)*

Agricultural Engineers in Water Management

By John A. Short

MOST of our water management problems in Missouri directly affect agriculture and are therefore of extreme importance to agricultural engineers as well as to civil engineers engaged in that field of activity.

My conception of an engineer has always been fairly well fixed in my own mind and can be described in a few words. An engineer is a person who applies scientific facts and natural laws for the purpose of improving the living conditions of mankind. The scientific facts and natural laws are brought to light by engineers and pure scientists as a result of research, experimentation, and mathematical analysis. Engineers should always base their actions and conclusions on established principles and not on hearsay or intuition.

Water problems in Missouri, for example, could be classified in various categories under many systems of enumeration. It would appear that major problems as far as they relate to agriculture could be listed as follows: Soil erosion, flood control, water conservation, land drainage, and possibly supplemental irrigation. This is not to say that other subjects, such as recreation, water power, fish and wildlife, navigation, stream pollution, and water supply, both industrial and municipal, do not affect agriculture. It seems, however, that these latter subjects would not ordinarily be of prime concern to the agricultural engineer.

The subject of soil erosion needs very little explanation or comment before a group of agricultural engineers, especially from a civil engineer. I believe we all realize the importance of the problem and the necessity for doing something about it. It can very logically be classed as a water management problem because fundamentally soil erosion in this area is caused by the runoff of water. As you know, there are many measures which can be taken to assist in the solution of this problem, although, relatively speaking, very little progress has been made to date. Some of you may disagree with this statement at first, but I believe that as engineers you will want to check the facts. Therefore, I invite you to examine the figures on the acreages requiring soil conservation measures as against those on which such measures have been applied, and then draw your own conclusions.

Flood control is a subject on which everyone seems to be an expert, excepting those of us who have studied the problem from an analytical point of view for many years. It seems to me that I knew more about flood control ten or fifteen years ago than I do at the present time. It is a popular pastime for people who have no facts or figures at hand and who have never taken the trouble to analyze the problem from even a reasonable layman's point of view, to expound at great lengths on various methods of controlling floods. Perhaps even some agricultural engineers have been guilty of such practice; I am sure many civils have.

Land drainage is a subject in which I know we will all be more interested as time goes on. This is a subject which is closely related to flood control and in many cases is a necessary adjunct to flood control. There are seven million acres of alluvial land in Missouri, most of which presents a problem either in land drainage or flood control, or both. Too often it has been assumed that the mere protection of land from flood waters would automatically reclaim the land and make it highly productive. A great expenditure would be made for flood control, only to find that an equal amount must then be spent for drainage in order to assure production. Sometimes it is found that the land was not susceptible to drainage and remained worthless even though flood protection had been provided. Who could have a greater interest in problems of this kind and be better qualified to solve them than the agricultural engineer?

Water conservation is becoming increasingly important to agriculture. Water for domestic and livestock uses is essential to operation of any farming unit. A well-distributed stock water supply is of particular importance in a balanced farming program. It is quite likely that water conservation for supplemental irrigation purposes will be a factor to be considered in the future.

It would seem that the importance of the subjects I have discussed is self-evident to the agricultural engineer. Now I would like to discuss some popular misconceptions with regard to these matters. Perhaps many of you will disagree with some of the statements I am about to make, and perhaps you, and not I, will prove to be correct. However, as one engineer to another I ask you to base your conclusions on facts and well-established laws.

On the subject of soil erosion I am not in a position to say just what misconceptions may exist. You are no doubt more familiar with those than I am. On the subject of flood control I could spend hours giving accounts of misconceptions and exploding theories. As I have said before, most of these misconceptions and ridiculous theories have come about through either no understanding of the problems involved or only a partial understanding. Some people greatly overestimate the seriousness of flood problems and are inclined to regard them of such importance as to be a threat to the very existence of our present economy. Others minimize the damage done by floods and tend to consider them as beneficial as they are destructive. They say floods are necessary to maintain the fertility of the soil and that it is not desirable to try and keep flood water from the land. Either conception is absurd when carried to the extreme.

Missouri could continue of course to be a great agricultural state even if no further flood protection were ever provided. On the other hand, we have only to point to the southeast Missouri lowlands, from whence approximately one-fifth of our agricultural production comes, to realize the economic importance of flood protection. There is no doubt that this area in southeast Missouri would be contributing very little to the economy of the state if it were not for the flood protection which has been so well provided over the years. There are many thousands of acres of alluvial land in other parts of the state which, in the aggregate, are very important and which owe their productivity largely to flood control. The idea that flood waters always increase the fertility of the soil is not true either. In many instances flood waters transport sand, gravel, and unfertile sediment on to land, either ruining or greatly reducing its productivity. Even in cases where increased fertility does occur through inundation by flood waters, it is often an expensive way to apply fertilizer. The loss of one crop on some of our rich alluvial land would buy a large amount of fertilizer for that land. Therefore, we must find a happy medium and a reasonable approach to the problem.

Theories on methods of flood control vary from one extreme to another. Some people believe that all flood damage can be prevented by the construction of large flood control dams; others suggest levees and channel rectification for the job. Some people say that comprehensive soil conservation measures will stop floods, and others would add small reservoirs to do the job. A few have proposed drilling wells in the river bed and diverting flood waters underground. As would be expected, all of these measures, except possibly the last one, have some practical application. However, none of them can be expected to accomplish the whole job, and each must be adapted to its own particular use according to its effectiveness.

Large dams can and will reduce floods on major streams below the point where they are installed and can completely eliminate floods down to a point where additional inflow provides enough water to produce a flood. They cannot, of course, control floods above the points where they are installed and where a large part of the agricultural damage occurs. Soil

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conservation measures, including farm ponds, terraces, and other water-control measures are effective in reducing floods and flood damage on small watersheds. However, the effects of these measures are so small on major streams that they are not measurable. "Small dam" like the term "large dam" is used very loosely and can mean whatever the proponent wishes it to mean. Dams of all kinds can only be expected to do their share in flood control and cannot be called the answer to all evil. In general, the smaller the dam the greater the cost per acre-foot of storage provided and the greater the area covered to provide an acre-foot of storage. Flood control is an expensive proposition at best and can be justified for agricultural protection only if costs are kept as low as possible.

Channel rectification is a measure which has often been used in the past to reduce flooding on certain lands; however, the improved channel almost invariably results in aggravating flood conditions downstream. Levees have been used with perhaps the greatest success of any widespread flood control method. Of course levees cannot be economically constructed in narrow valleys and they also have a tendency to aggravate flood conditions downstream by eliminating natural valley storage.

Certainly the agricultural engineer, especially in this state, should have a great interest in water management. There are many thoughts which I would like to leave with you for consideration on the subject. One of the first ideas I would impress on you is to attack the problem of water management in the same manner as you would attack any other engineering problem. Always base your conclusions and your actions on factual data and well-established natural laws. Never be misled by paradoxical or hypothetical ideas propounded by those who have made no real study of the subject. Beware of applying experimental data from small watersheds to large drainage basins.

Consider the limitations of every known method of flood control and make no wild assumptions as to what can be accomplished by any one method. Recognize soil conservation for what it is and don't let your enthusiasm for this worthwhile undertaking lead you to champion it as a method of flood control for major streams. Recognize that flood damage exists from the very upstream limits of the watershed to the mouth of the major stream and accept methods of water management which will tend to reduce these damages wherever they occur. Beware of taking experimental data expressed in terms of reductions in average annual flow and applying that to peak flood flow. Recognize the limitations of reservoirs for flood control. Never be led to a sense of false security just because a flood-control reservoir happens to have been constructed at some point in the basin upstream from you. You may be far enough downstream to still be flooded.

Do not assume that people who have studied flood control for many years and call themselves flood control engineers know nothing about flood control merely because they do not always agree with you. Study your soils before you undertake to drain them. Make sure the soil is adapted to the type of drainage practice you propose to employ and is worth draining. Recognize and anticipate the maintenance problems that accompany most drainage and flood control practices. Do not expect to use the same designs and factors of safety on major control structures that you would employ on farm ponds. Recognize water management and planning for what it is—a highly specialized, technical branch of engineering based on the practical application of scientifically established natural laws which no amount of wishful thinking can repeal.

Coordinating Joint Interests of Agriculture and Industry

(Continued from page 344)

into what is being done, what should be done, and the necessity for increased activity in a balanced fashion by the whole citizenry of the state. We feel also that through our relationships with other commercial and civic bodies, we are perhaps in the best position to obtain distribution of that information among all citizens.

I cannot answer for the other states, but in Michigan we have somewhat anomalous legislation today. We spend about $1,600,000 a year to protect our forests from fire and other hazards. We spend a little more than that for the protection of fish and game. In a normal year we might spend as much as $3,000,000 to $5,000,000 for the acquisition of park lands. Yet our state appropriation for soil conservation, out of which all of these stem, has been only $10,000. We are particularly concerned in our cities with water conservation. The River Rouge plant of the Ford Motor Company, I am told, uses as much water each day as all of the households of Detroit put together. We know, as do you, of a number of large industrial communities in the United States that are in grave and dire need of additional sources of industrial water. We are concerned directly and we believe that we, as much as anybody, can reach the other businessmen of the state with knowledge of what is requisite to be done for their protection. We ourselves are not experts on any of these things, but we are able to command the full cooperation and the best judgment of experts, which we in turn can disseminate.

We believe that much can be done to improve the broad terms of farm financing. Precisely what should be done is, in our opinion, a matter for deep and long-range studies conducted by those best capable of doing so—the bankers, the insurance companies who are interested in farm loans, Michigan State College, University of Michigan, Wayne University, and the Federal Reserve System. We are concerned in part because the banks have never appeared to look upon farming as an industry. The terms for the purchase of productive equipment and devices on farms are by no means similar to those extended to industry for similar purpose purchases. Perhaps that is wrong. We are concerned, too, because farming, like everything else, as it becomes mechanized and improved, requires larger capital outlays. A great many of the young aggressive, trained people who might make great contributions to the reduction of costs of production cannot be of full value until and unless they have their own businesses, and it has never been easy for a farmer to acquire a sufficient capital (not to be confused with bank loans) to put his farm in top-flight productive capacity. Is there a need for additional risk capital on farms? Is there any proper source of such capital, if it is needed? Is there some sort of a general acceptable agreement which can be devised between sources of capital and those on the farm who need that capital, so that both will be satisfied and so that the economy will profit? The answers are a part of what we are trying to find out.

We are interested in the health of the country. We, like you, are fully aware of the implications as to the national health of the figures on draft rejections, on dental deterioration, on the impact of nervous disorders, on the growing population of our mental institutions. We are led to believe by leading members of the medical profession that much of this may well be due to the fact that we are not a well-nourished nation, even though we may seem to be well fed.

I should like to repeat two things which I have said previously. One is that whatever industrialists and businessmen may do to help achieve improvement in agriculture is very definitely to their long-range direct advantage. The second is that businessmen must cease to consider agriculture as an activity apart from the rest of the business world and take the position that agriculture is a business and an industry, in fact the biggest single industry in the United States, as well as being the one upon which all business depends. To us in our Foundation, agriculture is basic. Despite all that has been done by those like yourselves and the agencies that you represent, despite all the research in industry which has made contributions directly or indirectly to the business of farming, that activity still remains among our most primitive in many respects. We feel that its salvation and thereby our own is going to come out of the continued sincere efforts of people like yourselves, fully backed by the facilities and the enthusiastic interests of the industries and the business firms of the United States, like those represented in our Detroit Agricultural-Industrial Foundation.

Building a Soil Deeper

By D. D. Smith, C. M. Woodruff, and D. M. Whitt
MEMBER A.S.A.E.

DEEP plowing accompanied by deep liming and fertilizing has produced a 31 per cent increase in yield of corn over normal methods on a claypan soil of central Missouri. Statistically, this yield increase is highly significant. The cost of the additional mechanical and fertility treatments was more than repaid by the increased yield from two corn crops at present prices.

The experiment was operated cooperatively by the soils department of the Missouri Agricultural Experiment Station and the Soil Conservation Service (Research), U. S. Department of Agriculture. It was based on preliminary laboratory work by C. M. Woodruff. A report[1] of the experiment was made at the November, 1946, meeting of the American Society of Agronomy.

The Problem. The claypan soils occupy an extensive area of the corn belt. They are generally medium to low in fertility, have poor internal drainage, and are commonly considered droughty and unsuited for growing of row crops such as corn. Their most desirable characteristic from an agricultural viewpoint is their level to gently rolling topography.

Numerous attempts have been made to improve these soils. Most have been unsuccessful. Physical and chemical studies[2, 3] have shown the nature of the problem and have suggested means of alleviating some of the undesirable conditions.

Water-holding capacity is related to the texture of the soil. In general, it increases as the clay content becomes greater. Fig. 1 shows how the clay content increases with increasing depth below the surface of the soil. This figure likewise shows the accumulated inches of water present when the soil is at field capacity. As the soil depth increases, up to about 30 in, the moisture-holding capacity increases at an accelerated rate. This might appear as a desirable characteristic. But, all of the moisture that may be present is not available to plants because of the high tension with which it is held by the soil. In other words, the soil moisture unavailable to the plant also increases with depth. This is also shown in Fig. 1. In the surface soil the available water, or that water between field capacity and the plant wilting point is about half that of the total capacity. As the soil depth increases and as the clay content increases, the available water capacity does not increase at as great a rate as the total water capacity. As a result, only 40 per cent of the total water in the 10 to 27-in zone is available to plants. There is probably little that can be done to increase materially the amount of available water-holding capacity.

Air volume with soil moisture at field capacity is about 26 per cent in the surface soil. It decreases sharply at a depth of about 15 in, and at 25 in is almost zero. It varies inversely with the clay content. Shattering the subsoil will increase this air volume in the lower horizons at least temporarily. This should provide a temporary reservoir above the unshattered subsoil for storage of an increased amount of rainfall.

Soil organic matter is an indication of soil fertility. It is generally between 2.5 and 3.0 per cent in the plow depth of cultivated claypan soils. It declines rapidly on going down into the gray layer and claypan where it is about one per cent or less. The growing of deep-rooted plants, like sweet clover, may increase the organic matter in the lower horizons if favorable conditions for deep-rooting are provided.

The capacity to hold plant nutrients in an available form is one characteristic of the soil which governs plant growth and development. Another characteristic is the amount of this capacity occupied by exchangeable plant nutrients. The first of these is referred to in soil science as exchange capacity and the second as exchangeable bases or nutrient ions. Fig. 2 shows the variation with depth in total exchange capacity and total exchangeable bases. These two factors are at a minimum in the gray layer. In a cultivated Putnam soil the organic matter in the surface layer would be less than for this virgin

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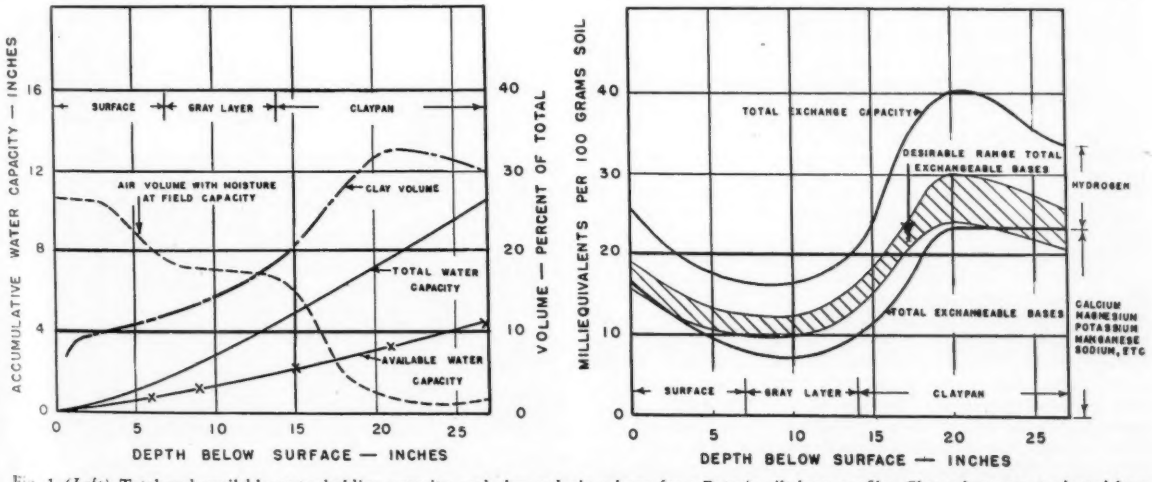

Fig. 1 *(Left)* Total and available water-holding capacity, and clay and air volume for a Putnam silt loam profile. Clay volume curve adapted from bulletin referred to in footnote 2, and water capacity and air volume curves from article noted in footnote 3 • Fig. 2 *(Right)* Total exchange capacity, total exchangeable bases, and the desirable range for total exchangeable bases for a virgin Putnam silt loam profile. Data from Table IV in bulletin noted in footnote 2 and unpublished data of the Missouri Agricultural Experiment Station

Fig. 3 The three steps in shattering, liming, and fertilizing the subsoil

profile, and thus the exchange capacity and total exchangeable bases in this layer would be little above the minimum points of these two curves. A minimum base saturation near 40 per cent occurs at a depth of 10 in. This increases to 60 per cent at a depth of 22 in.

Unpublished data of the Missouri Agricultural Experiment Station suggest that the desirable range of the total exchangeable bases is between 60 and 75 per cent of the total exchange capacity. This range is indicated in Fig. 2. Calcium is the most critical nutrient in this soil, and the application of sufficient lime will raise the total exchangeable bases to the desirable range. Liming the surface, however, will take care of little more than the plow layer. If 3 in of the surface soil of Fig. 2 had been lost through erosion, which is common on most of the cultivated Putnam, surface liming would correct the deficiency in the 3 to 10-in layer. Liming and shattering the subsoil would alleviate the deficiency in the 10 to 22-in zone. Two tons of lime would be required, in this case, for the surface layer and four tons for the subsoil layer between 10 and 22 in. Plant nutrients other than calcium are generally deficient in claypan soils. These should be added in the subsoil as well as in the surface soil to maintain the proper balance of nutrients and to secure maximum plant growth and development.

The Experiment. The plots of the experiment were installed in September, 1941. They consist of three replications of 9 plots, on which each crop of a 3-yr rotation is represented each year for each of the following three conditions:

1 Normal plowing without disturbing the subsoil.

2 Deep surface plowing followed by plowing in the bottom of the furrow of the first plow to a total depth of about 18 in, resulting in shattering of the subsoil.

3 Double plowing as in 2, with two tons of limestone and 200 lb 8-20-10 fertilizer per acre mixed with the shattered subsoil.

The 3-yr rotation selected was (a) oats and lespedeza with the lespedeza to be plowed under as a green manure, (b) winter barley with spring seeding of sweet clover to be plowed under the following spring as a green manure, and (c) corn. The three grain crops are harvested for grain with the cornstalks remaining on the field and the oat and barley straws removed. The surface was limed, 3 tons per acre on all plots, and 100 lb per acre of 0-20-10 fertilizer was used with both the oats and barley. It is planned to repeat the shattering and deep fertility treatments after six years, or two cycles of the rotation. The plastic nature of the subsoil requires that shattering be done only when the moisture content is about 12 per cent or less. Fig. 3 shows the three steps in the mechanical and fertility treatments. Slippage of the right tractor wheel operating in the furrow after spreading of the lime and fertilizer mixed these amendments with the shattered clay.

Results. The average yields of corn, winter barley, and oats during the 4-yr period 1943-46 are shown in Table 1. The corn on the shattered plots has consistently and significantly outyielded that on the check plots. This is probably due to the increased aeration as the result of the shattering. The largest increase in corn yield, however, was secured when the lime and fertilizer were mixed with the shattered subsoil. In this case the yield increase was highly significant. It is considered the result of (a) the increase in the percentage base saturation of the soil brought about by addition of the lime and fertilizer, (b) a higher nitrogen content resulting from the plowing under of a heavier growth of sweet clover as green manure, (c) improved subsoil aeration brought about by shattering, and (d) possibly a small increase in soil moisture.

TABLE 1. AVERAGE YIELDS OF CORN, OATS, AND BARLEY FOR SUBSOIL SHATTERING AND SUBSOIL SHATTERING WITH LIME AND FERTILIZER TREATMENTS FOR THE FOUR-YEAR PERIOD, 1943-46
(Yields in bushels per acre)

Crop	Undisturbed subsoil	Shattered subsoil	Shattered subsoil with lime and fertilizer
Corn	24.5	29.7	32.0
Oats	31.9	30.9	32.9
Barley	20.3	16.7	20.1

The yields of corn have been low on these plots. No surface fertilizer was used on the corn, and only light applications were used on the other crops. It is now considered that the subsoil treatments of lime and fertilizer were also too low. Chinch bug and grasshopper damage contributed to the low yields. The corn yield on the Putnam soil is normally about one-half that of the better corn soils of the state.

The yield of winter barley on the shattered plots without the lime and fertilizer was significantly lower than that on the check plots. This is undoubtedly the result of some mixing of the shattered subsoil with the surface soil. Barley is particularly sensitive to an acid soil condition. When the subsoil had been shattered and limed, the yield of barley was not depressed.

The oat yields were not significantly affected by either the mechanical or fertility subsoil treatments.

The subsoil treatments have had a profound effect on the development of the sweet clover roots. This is shown in Fig. 4. With shattering, liming, and fertilizing of the subsoil, the sweet clover roots have grown deeply with only a limited amount of branching. They penetrated the full depth of the treatments. Without shattering or fertility treatments the roots did not develop normally but were short with numerous branch roots extending laterally and downward from just below the crown of the plant. There was some tendency for a deeper and less branched root system to develop on the shattered plots that did not receive the deep *(Continued on page 353)*

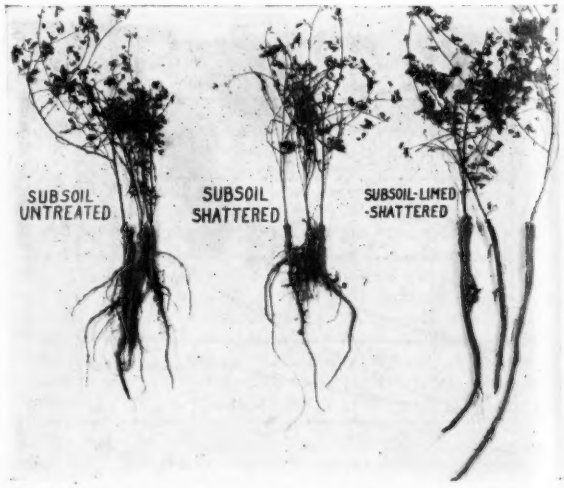

Fig. 4 Development of sweet clover roots under (a) normal plowing without subsoil treatments, (b) shattering of the subsoil, and (c) shattering, liming and fertilizing of the subsoil

Soil Erosion Studies—Part V

Soil Transportation in the Splash Process

By W. D. Ellison
MEMBER A.S.A.E.

THE two principal erosive agents that become active during rainstorms on the land are falling raindrops and flowing surface water. Each of these is a complete erosive agent within itself, because each will detach and transport soil materials. The soil detachment caused by falling raindrops was discussed in a previous paper[1]. Soil transportation that is caused by these splashes is also an important function in soil erosion processes, and it is to be the subject of this paper.

As a first step in discussing soil transportation by the splash erosion process, identification will be made of some of the principal factors involved in soil transportation by the splashes. It is not generally recognized that relatively large amounts of soil can be transported by the raindrop splashes acting alone. The samples shown in the lower view of Fig. 1 have lost approximately one inch of soil through transportation by splash, during 1 hr and 15 min of rainfall.

Splashing soil particles will mostly reach heights of less than one foot, but some few of them may reach heights of more than two feet. Their trajectories are shown in Fig. 2. This photograph was made with 1/25-sec exposure, and shows the general shape of the paths taken by the splashes. Most of the trajectories are parabolic, and we may assume that their horizontal movement will be about four times the height of their rise.

A favorable place for observing transportation by splash is on a large sand pile that is free of surface flow. The top of the pile will be lowered by splashing the sand particles downslope, while sand at the lower edge will be piled deeper and the pile made wider. The results of this same process are apparent on many small knolls and hummocks, and along the crests of many hills. Fig. 3 is typical of these conditions, where the crests of hummocks, knolls, and steep hills, in cultivated fields and on overgrazed pastures, are often devoid of topsoils while a deep bank of topsoil may be found along the base of the slope. Examination of these soil banks will often show that they do not have the characteristics of alluvial deposits, and it appears that transportation of soil in the splash process may have been a major contributing factor.

In some experimental work[2] at Coshocton, Ohio, it was found that many of the heavier soil particles and aggregates, when splashed into the air by the impact of raindrops, moved horizontally from several inches to more than a foot, while the lightest particles were sometimes splashed 3 to 5 ft horizontally on level surfaces. Soil particles splashed in downhill directions were carried farther than those splashed in uphill directions, the differences being a function of the degree of slope. Because of these differences in distances of splash, the particles in being resplashed many times would migrate toward the base of the hill.

Another important factor which affects soil transportation by splash is the prevailing direction of the splashes. On a 10 per cent slope where there was a small amount of surface flow, considerably more than half of the particles that were splashed moved in downhill directions. This, too, tended to cause the splashed soil to migrate toward the base of the slope. One reason for more of the splashes moving in downhill than in uphill directions is to be found in the angle of impact. On the hillside the raindrop will tend to strike a glancing blow, and this causes the splash reactions to tend in downhill direc-

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[2]Studies of Raindrop Erosion, AGRICULTURAL ENGINEERING, May, 1944, vol. 25, no. 4, pp. 131-136; May, 1944, vol. 25, no. 5, pp. 181-182.

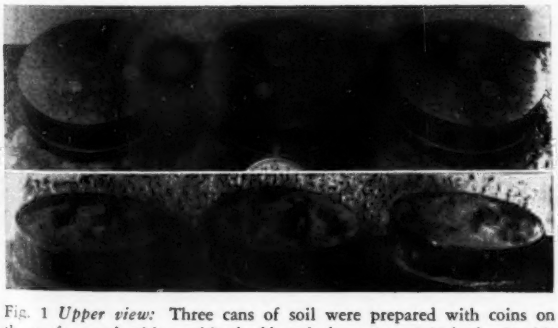


Fig. 1 *Upper view:* Three cans of soil were prepared with coins on the surface and with a white backboard about 4 to 6 in back. In this view rainfall had been applied for 45 sec. *Lower view:* Same cans as shown above, but after 75 min of rainfall. Soil loss was mostly by the splash process. Note soil on white backboard

Fig. 2 This photograph of falling raindrops (the long vertical lines) and splashing particles of soil and water (the curved lines) was made with 1/25-sec exposure to record shapes of paths taken by splashing particles. Lighting at top of view was inadequate to show full height reached by the highest splashes. The top of photograph is about 22 in above the surface of the soil. The light beam was only about 6 in wide, and it was directed across the soil surface at right angles to this view. This arrangement made those particles splashing toward the camera, as well as those splashing away from it, pass out of view very quickly

Fig. 3 A typical view of hilly, cultivated fields. Here the greatest soil loss per unit area is found on the shortest slopes and at the crest of the hill. Surface flow is least effective at these locations, and it is apparent that splashing raindrops play a major role in producing this erosion. Near the base of the slopes, where surface flow is greatest, the soil loss is least. (Compare this phenomena with that on sand piles, where there is no surface flow)

tions. Water on the soil surface will tend to increase the percentage of splash moving in downhill directions, particularly if there is some surface flow.

Wind, too, can have an important effect on the transportation of splashed particles. If the winds which accompany heavy rainstorms tend to alternate in directions from storm to storm, their long-time effects will tend to sum up to zero. However, if most of the major storms are accompanied by winds from a single prevailing direction, transportation of splashed soil by wind may cause considerable soil loss from a field.

Where the surface of the land is smooth and level, and where the soil is only splashed back and forth across the surface without transporting it off the field, the transportation factor is not important. The soil will probably be damaged in the splash process, but the correction for these damages will be to reduce the soil detachment hazard (D_1). However, on sloping land where most of the splash moves in downhill directions, and on fields where prevailing winds tend to transport soil in a single direction across the surface and off the field, some control of this soil transport by splash may be desirable, even beyond the point of reducing the D_1 factor to a practical minimum.

Our method of approach in studying this problem is to first determine the transportation hazard (T_1) for a smooth, level surface, with no wind (a standard surface)[3]. Obviously, if the soil on this standard surface is of low transportability, and if the transporting agent which splashes the soil particles into the air is of low transporting capacity, the amounts of soil that can be moved off a steep hillside will be relatively small. But, if on our standard surface we have a soil that is highly transportable, and if the transporting capacity of the splashes is high, so that splashed soil particles are carried considerable distances horizontally each time they are splashed, then amounts of soil that can be splashed off a steep hillside, or transported across the field surface by wind, will be relatively large. Because of this, our first step must be to determine the transportabilities of different soils and the transporting capacities of splashes that are associated with the different storms.

The relationship for the principal factors that affect soil transportation on a standard surface will be of the general form

$$T_1 = f(T_2, T_3, D_1) \quad [1]$$

where T_1 = the transportation hazard

T_2 = the transportability of the soil

T_3 = the capacity of the transporting agent

D_1 = the soil detached by splash; it represents the quantity of soil per acre in transport by splash.

The transportation hazard on the standard surface represents the first step in this study, and after it has been measured, the next step is to introduce modifying factors one at a time and determine their effects on (a) giving direction to this soil transportation and (b) increasing the transporting capacity of the splashes, and thereby causing increased soil losses from fields. The first step of evaluating T_2 and T_3, so as to determine the transportation hazard (T_1), will now be presented

Transportability of Soil, (T_2). Some tests were carried on at Coshocton, Ohio, in 1943 to determine the relative distances that different particle sizes would be carried by raindrop splashes (soil transportabilities). The standard surface condition previously described was used in this work, and the distances that different particle sizes were splashed were determined by catching the splashes on a plane that was level with the surface of the plot. This catch was made while applying simulated rainfall of known drop size, drop velocity, and rainfall intensity.

The small rainfall applicator[1] mounted on a truck can be used for these tests of soil transportation. It is necessary to use a narrow plot, and a soil plot 6 in wide by 3 ft long is recommended. The splashes moving out to each side of this plot should be caught in such a way that the pounds-feet of transportation of each different soil tested can be computed. The catch can be made on narrow strips of oven-dried paper (6 in wide and 3 ft long), weighed before the test (Fig. 4). After the test, these paper strips that now contain the splashed soil are again oven-dried and weighed and the amount of soil on each is multiplied by the distance in feet to obtain the foot-pounds of transportation caused by the splashes. The results are to be expressed as relative values, to compare one soil with another. But before making this comparison, it will be necessary to make a correction for amounts of soil splashed.

There will be more soil splashed on those soils of high detachability than on those of low detachability. Because of this, it is necessary to divide the amount of soil on each 6-in strip of paper by the total amount of soil splashed before

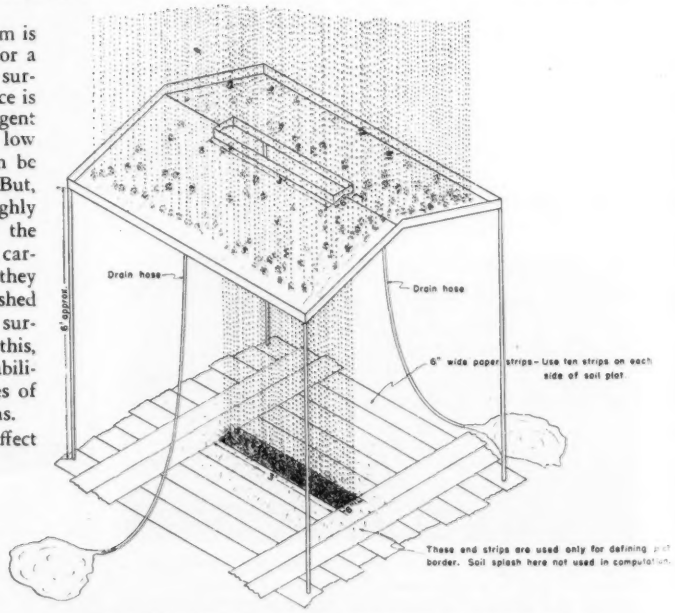

Drain hose
Drain hose
6" wide paper strips—Use ten strips on each side of soil plot
These end strips are used only for defining plot border. Soil splash here not used in computation.

Fig. 4 This drawing shows the arrangement for determining soil transportation by raindrop splash

[3] For the standard surface, the upper inch of the soil to be tested is passed through a screen with ¼-in openings, and a straightedge is used to make it flat and level on the plot.

Fig. 5 Splashes of soil and water on an area where the surface is 75 to 80 per cent covered by vegetation. In addition to intercepting raindrops and thereby reducing the soil splash, these plants also intercept splashes and thereby reduce soil transportation

multiplying by distance of splash.[4] After this has been done the T_2 values obtained for the different soils can be compared one with another, directly. It will be important that we compare T_2 values of different soils in this way, in order that we may know what properties of the soils are responsible for differences in their transportabilities. Often the T_2 factor may be decreased by improving the state of aggregation of a soil, so that the splashed particles are made less transportable. There will be other properties of soils, too, that will affect the soil's transportability factor (T_2).

Transporting Capacity of the Splashes, (T_3). The transporting capacities of the splashes may be obtained with the same rainfall applicator and plot arrangement as was used to obtain T_2 values of the soil. This can be done by using standard soil[1] on the plot, and by varying rainfall characteristics from one test to another. The foot-pounds of transportation of the standard soil will be proportional to the transporting capacity of the splashes.

The D_1 Factor in the Transportation Equation. Methods of evaluating the D_1 factor were given in a previous paper.[1] The importance of this factor in the transportation equation is quite obvious. Having determined the transportability of the soil, and the transporting capacity of the splashes, the other dimension needed to define the amount of transportation is the quantity of soil involved in the splash process. This is represented by the D_1 factor, and it will vary from one soil to another, as well as from one rainfall to another. It will also vary with soil covers which impede the falling raindrops.

Other Factors that Affect Direction and Distance of Splashes and Thereby Affect the Soil Loss. Included in this group are four factors that will modify results produced by splashes in moving soil off a field, when there is present on the field a transportation hazard (T_1). Two of these are natural factors which by giving direction to the splashes, and increasing the movement in a particular direction, will increase the soil loss. They are the factors of slope and wind. The other two are factors that we manipulate to check the effects of slope and wind. They are the factors of surface condition and impediments to splash.

It is apparent that the results produced by slope or wind will depend on how high and far the splashes are carrying, and on how much soil is being splashed. The heights and distances of splashes are dependent on T_2 and T_3, and the amounts of soil being carried depend on the D_1 factor. These three factors were combined in equation [1] to produce the T_1 factor. We may now use another relationship to express soil loss by transportation in splash (T_{loss}), that will result from a condition of slope or wind. This relationship will be of the general form

$$T_{loss} = f(T_1, \text{slope, wind,}) \qquad [2]$$

In addition to exploratory studies of T_2 and T_3, carried on at Coshocton in 1943, some effects of slope were measured. More work is necessary, however, before the functional relationships of factors in equation [2] can be evaluated.

To evaluate slope, the experimental setup used for evaluating T_2 and T_3 may be used. In this work the plot surface will be sloped, (from side to side, in the 6-in dimension) and the splashes will be caught at different elevations. The up-and-down slope splashes will be caught at elevations corresponding to projections of the surface slope. The upslope splash expressed in foot-pounds is then substracted from the corresponding downslope splash to determine the effects of slope on transporting soil downhill by the splash process.

No measurements have yet been made of the effects of wind, and the equipment used in evaluating the other factors of the transportation process does not seem suitable for working with the wind. New techniques will be needed for the wind experiments.

Surface Conditions and Impediments to Splash. Differences in surface conditions that will have considerable effect on the direction of splash may be caused largely by differences in contour ridges. By making contour ridges very close together, such as on each crop row, on a hillside, most of the splashes from the uphill sides of these ridges may be directed upslope. This will tend to modify the effects of slope and wind by giving direction to the splashes at the point of origin. It should not be necessary to run experiments to evaluate the effects of these ridges, but computations should be made based on the percentages of splash they will direct uphill.

Fig. 5 shows splashed particles of soil and water on an area where the soil is 75 to 80 per cent covered and protected by growing vegetation. The full height of this view is from 14 to 15 in. Most of the vegetation is 4 in to 8 in high, and in the picture one can see that some of the splashes are moved considerable distances horizontally over the tops of the plants. All of these splashes contain some soil, and they originated at the ground surface and not from plant leaves. The leaves of plants are not rigid enough and the water films on the leaves are not sufficient to cause many splashes to be thrown upward from their surfaces. The very large leaf in the left background shows particles of soil that were deposited there by the splashes. These particles will soon to be washed down by the falling raindrops. We cannot determine how much soil is splashed merely by examining plant leaves and other objects above the ground, because the splashed soil does not usually remain there during the storm, but it is usually washed down at about the same rate that it is splashed up.

The impediments to splash are composed of such things as stems of close-growing crops, either in drilled rows or broadcast. These will intercept the moving splashes and restrict distances of their travel. Methods should also be devised for computing the effects of these, although some experiments may be necessary to establish the validity of assumptions on which the computations may be based.

SUMMARY AND CONCLUSIONS

Very large amounts of soil may be transported down steep hillsides by the splash process. So much so that it becomes important for us to evaluate this form of soil transportation. Such evaluations will help us to gain a better understanding of the soil erosion processes, and to better understand the causes for many erosional deposits. Undoubtedly this form of soil transportation has great geologic significance on many steep slopes, as well as on areas where most of the heavy rainstorms are accompanied by winds from a single direction. It must also be a highly significant process affecting what we usually term accelerated erosion on steep hillsides.

Based on observations and experimental studies of the splash erosion process, it is the author's belief that on certain highly permeable soils, on very steep slopes, the splash process may cause about as much down- *(Continued on page 353)*

[1] Example of computations: If there is a total of 10 lb of soil splashed on to the paper strips, and, say, 2½ lb of this is on each of the strips that join the plot (there are two of these strips, one on each side), the pounds-feet of transportation will be $(2\frac{1}{2}+2\frac{1}{2})\div 10\times(\frac{1}{2}\text{ ft})=\frac{1}{4}$. This ½-ft distance is figured from the center of the 6-in plot to the center of the 6-in paper strip.

Recommendations for Mechanical Conditioning of Soft or High-Moisture Corn

THE general recommendations on methods of utilizing, handling, and storing soft or high-moisture corn are well known to farmers in the corn belt. These recommendations include such practices as the following:

1 Ensiling both fodder and shelled corn
2 Sorting and early feeding of soft corn to hogs or other livestock
3 Delayed harvesting to allow maximum drying of ear corn in the field
4 Clean husking to eliminate trash that reduces ventilation in the crib
5 Use of screens on the elevator to screen out shelled corn, silk, or other trash
6 Good distribution in the crib to avoid pockets of shelled corn and debris where spoilage is most likely to start
7 Storage of corn of highest moisture content in the narrowest cribs to facilitate natural ventilation
8 Use of adequate ventilators in cribs.

Detailed information on such practices is given in Farmers' Bulletin 1976, "Handling and Storing Soft Corn," published by the U. S. Department of Agriculture, and in bulletins of the state agricultural colleges.

The use of forced-air ventilation for drying on the farm, both with and without added heat, is a comparatively new practice. Because of the probable high-moisture content of a large part of the 1947 crop, use of this method may be required on a large number of farms to insure the safe keeping of this corn. Based on present research results, the following recommendations can be made:

Mechanical Ventilation Without Heat. This method of ventilation may be used for ear corn with a moisture content ranging from 20 to 28 per cent. For unheated air a volume of 5 to 10 cfm (cubic feet per minute) for each bushel of corn is suggested. With corn having a moisture content of 24 to 28 per cent, drying can be accomplished only after long periods of operation. For example, to reduce the moisture content from 28 to 20 per cent may require several weeks. Drying will probably not be completed before winter. Further fan operation may therefore be necessary after the weather has started to warm up in the late winter or early spring.

Operation of the Fan. Operate the fan only when weather is favorable for drying, using temperatures above 50 F (degrees Fahrenheit) as a rough guide. Better and more rapid drying will be possible at 60 F or more. On clear days relative humidity usually is low enough, especially in fall and winter. Good drying will occur at 65 per cent relative humidity and lower. The fan may be operated either by electric motor, tractor, or gasoline engine.

Mechanical Ventilation with Heated Air. Use of heated air has certain advantages. It shortens the time of drying, and permits drying to continue even in weather when it would be impossible without heat. With corn of extremely high moisture content, it may be possible to dry it only if heat is used. Excessively high temperatures of heated air will, however, result in damage to corn that is to be used for some purposes. Except when the corn is to be used as seed, temperatures below 130 F apparently do not cause damage.

Flue gas or smoke from an oil burner are usually mixed with the air forced through the corn in seed corn driers without any apparent bad effect on the corn. If coal is used for fuel, the smoke might be objectionable, but if coke is used, there should be no objection to forcing the flue gas through the corn. From 20 to 50 per cent of the heat value of the fuel is lost if the smoke is carried off in a chimney or flue.

Some precautions should be taken against fire. Air entering the furnace should be screened to prevent entrance of husks, and an additional screening of flue gas leaving the furnace is desirable if flue gas is put in with air forced into the crib. Ducts close to the furnace should be of all-metal construction. The burner should be provided with an automatic cutoff so that in case of a fan failure excessive temperatures will not develop.

Heater and Fan Capacities. Assuming that oil is to be used as fuel and the flue gases are to be discharged into the drying air, the recommended capacities of heaters and fans for drying 1,000 bu of ear corn having a moisture content of 30 per cent or more are given in the following tabulation:

With this heater capacity	With this fan capacity	Approximate drying time will be
4.0 gal per hr	5,400 cfm	4 to 6 days
2.0 gal per hr	3,600 cfm	8 to 12 days
1.0 gal per hr	2,700 cfm	16 to 24 days
0.5 gal per hr	2,700 cfm	32 to 48 days

With corn of higher moisture content the time required for drying will be longer, and with lower moisture content corn it will be shorter than shown in the tabulation.

The temperature increase of the heated air equals 108,000 times the number of gallons of fuel per hour divided by the cubic feet per minute of air volume. For example, with a fuel rate of 2 gal per hr with 3,600 cfm the increase in air temperature of the heated air will be

$$(108{,}000 \times 2) \div 3{,}600 = 60\ \text{F}$$

Air Temperature. The estimated drying times in the above tabulation are for an outside air temperature of about 50 F. When the weather is warmer, drying will be faster. In colder weather, drying will be slower. For example, if the air is 20 deg warmer, the time for drying will decrease about one-fourth. If it is 20 deg colder, drying time will increase by about the same amount. It is advisable for efficient drying that the heated air always be above 50 F. In very cold weather, it may be necessary to restrict the air delivery of the fan to keep the heated air temperature from dropping below 50 F. The air delivery can be restricted by closing off part of the air intake or outlet or by reducing the speed of the fan.

Other Fuels. One gallon of oil is equal in heating value to 11 lb of coal, 9 lb of coke, 20 lb of dry wood, 6 lb of bottled gas, or 20 lb of dry corncobs. A higher number of pounds will be needed if some of the heat is lost by failure to discharge smoke and flue gasses through the corn. This increased requirement may be as much as 25 to 100 per cent of these amounts of fuels.

Adapting Cribs to Ventilation with Fans. Farm cribs can be adapted for mechanical ventilation. In a double crib the driveway can be sealed to prevent air leakage by covering all openings and cracks around doors with building paper. Cover driveway crib walls back about four feet from the doors to prevent air from short-circuiting. Air blown by the fan into the driveway will then escape horizontally through the cribs. In the case of a single crib, an air duct of temporary framework covered with reinforced kraft paper can be built along one side of the crib.

It is important to husk the corn as cleanly as possible, but any shelled corn and husks which may remain should be distributed uniformly throughout the crib. Air flow will bypass any point where these materials accumulate.

Equipment and Drying Facilities. Where hay-drying equipment is available, it can be used to good advantage in drying ear corn.

Equipment supplies for conditioning corn will be limited. Early ordering by farmers and custom operators is advisable. Manufacturers of lumber and other materials, motors, fans, oil burners, and other needed units can help by seeing that dealers in rural areas have equipment on hand when needed by farmers.

Seed corn driers and country elevators can dry some wet

EDITOR'S NOTE: These recommendations were prepared by a special committee appointed at the Conference on Conditioning the 1947 Corn Crop held at Chicago, Ill., July 21, 1947, under the sponsorship of the American Society of Agricultural Engineers, in cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering (USDA) and state agricultural experiment stations and other agencies.

corn, but their capacity is not large enough to handle the amount of high-moisture corn that is expected from the 1947 crop. Corn will be saved by making full use of all available means of drying.

State and County Meetings. The great interest in the corn conditioning problem shown at the Conference on Conditioning the 1947 Corn Crop held at Chicago on July 21, indicates the difficulty farmers may face in caring for the 1947 crop. Additional state and county meetings to advise farmers on recommended practices will help solve the problem.

Effect of Variation in Soil Water on Yield and Quality of Potatoes

By J. F. Cykler
JUNIOR MEMBER A.S.A.E.

THIS article briefly summarizes irrigation experiments conducted in 1941, 1942, and 1946 on the effects on yield and quality of potatoes when available soil water was held at various levels. The experiments duplicated, in the field, experimental procedure outlined in a previously reported greenhouse trial.[1] Both series of trials were conducted at the Wyoming Agricultural Experiment Station at Laramie.

If an irrigation method can be developed by the use of some simple soil moisture indicator, and if the zones of available moisture which produce maximum growth and quality of crops for main soil types can be found, we have then arrived at a basis where the weather, the soil, and the crop can be integrated to give us a means of knowing when to irrigate and how much water to apply per irrigation.

The four irrigation treatments used were as follows:

1 *Minimum Variations* in the available moisture content of the first 3 ft of soil. The average moisture content was held at above one-half the difference between the moisture content at field capacity and at permanent wilting point. Whenever moisture dropped to this level, it was replenished to field capacity. Lowest level of moisture in per cent moisture equals $(FC-WP)/2+WP$.

2 *Medium Variations* in available moisture. Lowest level of moisture in per cent moisture equaled $(FC-WP)/3+WP$.

3 *Wide Variations* in available moisture. Whenever the average moisture content of the first 3 ft of soil approached within 5 per cent of the *PWP*, it was replenished to *FC*. Lowest level of moisture in per cent moisture equals $(FC-WP)$ 0.05.

4 *General Practice.* The guess method of irrigation as practiced by a successful farmer.

Sampling prior to planting. Before planting a careful study was carried out on the soil within the area selected for the experiment. At least 6 sampling holes were dug by hand to a depth of 3½ ft, and these were located within the experimental area. The soil was broken up into its respective horizons, and each horizon was studied separately for such physical and chemical information as outlined in a former paper.[1]

In the 1946 trial, piezometer wells made from ⅜-in pipe were used to study the depth of the water in order to check on subirrigation. The effect of the gravel in the soil was studied to find the relationship between the gravel content and the moisture percentage. It was generally found that the moisture content, corrected for gravel, was approximately one per cent higher than the uncorrected values for the soils in this particular area.

Rectangular weirs, in conjunction with Friez *FW*–1 water-level recorders, were installed to find the applied and waste water from the plots. The water which collected in the field ditches was determined. The field ditch losses, such as deep percolation, were not taken into account.

By continuous soil sampling to 3-ft in six locations per treatment, the time to irrigate was determined. Since the average thickness of each horizon varied, a weighted mean average was used for the volume weight, field capacity, and wilting point determinations, to give a single-valued figure for the soil area. In the 1941 trial, moisture sampling was done at random locations within each treatment. In the 1942 and 1946 trials definite places within each treatment were selected, and moisture sampling was done within a 3-ft radius of these base points. These six samples per treatment per horizon were averaged to give a single-valued moisture content per treatment. When the average moisture content was lowered from field capacity to one of the three irrigation treatments listed, then water was added to the plot.

Bliss Triumph certified seed was used in all trials. Seed was dipped in mercuric chloride prior to planting. Plant mortality was determined by plant counts near the frost period. Yields were corrected from these counts. Temperature, humidity, wind velocity, and rainfall figures were obtained from the weather station.

There is a very close relationship for all treatments in the pounds of net irrigation per pound of tubers. There was also a close relationship in the medium and wide treatments in pounds of water transpired and evaporated per pound of tubers. This comparison cannot be made with the minimum and general practice treatment, due to erratic moisture sampling in the 1942 trial on the general practice plots, and to the shortage of irrigation water in the 1946 trial on the minimum variation treatment. The measure of total pounds of water per pound of tubers gives very close comparisons. The number of irrigations for each treatment was about the same for each year.

CONCLUSIONS

1 High yields and quality can be attained by frequent irrigations where a medium moisture level is held in the soil, to a depth of 3 ft. The per cent moisture should never be reduced below two-thirds of the way from field capacity to wilting point.

2 Daily moisture extraction in the form of transpiration and evaporation on fine sandy loam to loam soil varies from 0.05 in in treatments with one irrigation, to 0.31 in in treatments with six irrigations. Average figures are close to 0.15 in water per day.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

J. F. CYKLER is agricultural engineer, Wyoming Agricultural Experiment Station.

[1] Cykler, J. F. Effect of Variations in Available Soil Water on Yield and Quality of Potatoes. AGRICULTURAL ENGINEERING, vol. 27, no. 8, pp. 363-366, August, 1946.

Building a Soil Deeper

(Continued from page 348)

fertility treatments, but this was not nearly as extensive as where the subsoil was shattered, limed, and fertilized. There was less damage by heaving on the plots where the subsoil was shattered and treated than on the check plots. The lime treatment, coupled with that of the shattering, is considered almost wholly responsible for the desirable development of the sweet clover roots on the shattered, limed, and fertilized plots since the amount of fertilizer used was small and applied only at the beginning of the experiment in September, 1941.

Soil samples have indicated somewhat greater moisture on the shattered plots than on the check plots during the spring, but this difference disappeared during the summer months under the growing corn.

Soil Erosion Studies

(Continued from page 351)

hill transportation as does the surface flow, possibly even more.

The factors affecting soil transportation are many and complex, and it is extremely important that we make a fundamental grouping of these factors, if we are to obtain most usable results. The grouping of factors and the order of their study presented in this paper are based on considerable experimental work and several years of study of this and related problems.

Use of Insulation Board in Laying Houses

By H. B. White and A. R. Schwantes
FELLOW A.S.A.E. MEMBER A.S.A.E.

IN THE summer of 1943 the University of Minnesota entered into a cooperative research agreement with The Minnesota and Ontario Paper Company for the purpose of constructing and testing a poultry laying house employing insulation board as insulation and sheathing. Such a building, known as house No. 1, was constructed at University Farm in St. Paul, Minn., and tests were conducted in it during the winter of 1943-44.

As a result of findings from this test, it was decided to expand the scope of the project and construct two additional buildings. During the summer of 1944 one of these, house No. 2, was built in St. Paul near house No. 1, while house No. 3 was built at the Northwest School and Experiment Station of the University of Minnesota at Crookston. This location was chosen for house No. 3 because its winter-time temperatures are consistently substantially lower than at St. Paul, a minimum of –51F having been recorded in February, 1936. The lowest official temperature recorded in St. Paul was –34F in January of the same year.

Tests were conducted in all three buildings during the winters of 1944-45 and 1945-46.

Photographs 1 and 2 show the test houses. All have 25/32-in uncoated insulation board sheathing on the exterior of the walls, without cover or protection, except that it was painted with one and two coats of water-reducible resin paste paint. Likewise 25/32-in insulation board sheathing was used on the interior surface of all walls as well as on ceilings and roofs. The board on some interior wall and ceiling surfaces was variously treated as described later, while the roof sheathing was covered with roll roofing. Several kinds of hard-surface materials were used to prevent damage to the walls by the hens.

All of the buildings are 24 ft by 23 ft 9 in outside dimensions. The front and rear walls of houses Nos. 1 and 2 are uniformly 5 ft 6 in high (floor to cove) while they are 5 ft and 3 ft, respectively, in house No. 3. Height from floor to finished ceiling in Nos. 1 and 2 is 6 ft 2 in; in No. 3, 6 ft 4 in.

The four 9x12 four-light sash provide considerably less window area than is usually recommended. Storm sash were used on all buildings for all tests. Dutch doors, built on the job of two layers of 25/32-in insulation board separated by a ¾-in air space were used in all buildings. Foundation and floor construction are as shown in Fig. 10.

Photograph 3 shows a typical interior. The same type of nests and roosts were used in all three buildings. The photograph shows location of some of the recording instruments.

Houses Nos. 1 and 2 (St. Paul) are practically identical, the chief difference being the distribution of the four windows and door along the south front wall. House No. 3 (Crookston) has only the four windows in the south wall, the door being in the east wall.

As the project developed, changes were made by the addition to the buildings of various insulating materials other than insulation board, and by varying construction slightly. This resulted in six types of construction as shown in Fig. 1. Note that only Type F was used in house No. 3, the other variations all being used in houses Nos. 1 and 2, which are constructed essentially alike.

Methods of Ventilation. Ventilation in the test buildings was by means of straw loft, natural draft flue, and fan.

In the building (No. 1) where the first two methods were employed, two separate 22x5-in air inlets were provided and all windows kept closed. These inlets were placed one each on the east and west walls near the south wall of the building. A duct, open at the bottom, extended down on the outside of the building to 30 in below the wall opening. This may be noted in Photograph 1. An adjustable baffle (to regulate size of opening) was used on the inside.

In this building, also, a 36x30-in ventilating opening was provided in each gable end and fitted with 1x4 adjustable wood louvers, for ventilation of the loft. Similar non-adjustable louvered openings were made 8x12 in in houses Nos. 2 and 3 where only fan ventilation was used.

For straw loft ventilation, about 20 in of straw was placed over the entire ceiling, the sloping portions between cove and roof at north and south sides being well filled. A 12-ft-wide strip of ceiling area in the center of the building extending from the east to the west wall contained only 1x4 wood strips spaced 7 in on center. The remainder of the ceiling was covered with insulation board sheathing.

The air outlet flue for natural draft flue ventilation is visible above the roof of house No. 1 in Photograph 1. A 27x27-in roof was originally installed about 8 in above the top of the flue, supported by the four corner 2x2s which extended to that height. The removal of this roof did not affect results. Flue size is 12x12 in inside dimensions, less the space occupied by corner 2x2s. The flue walls are single thickness (25/32-in) insulation board. A damper was installed in the flue; also, provision was made to open the flue at the ceiling and close

This paper was presented at the fall meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1946, as a contribution of the Farm Structures Division.

H. B. WHITE is assistant agricultural engineer, Minnesota Agricultural Experiment Station, and A. R. SCHWANTES is agricultural engineer, Insulite Division, Minnesota and Ontario Paper Co.

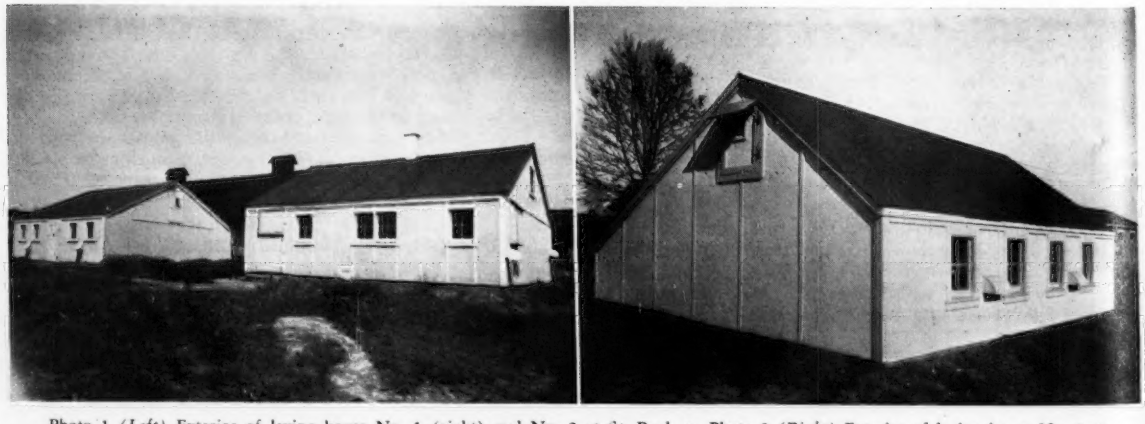


Photo 1 *(Left)* Exterior of laying house No. 1 (right) and No. 2 at St. Paul • Photo 2 *(Right)* Exterior of laying house No. 3 at Crookston, Minn.

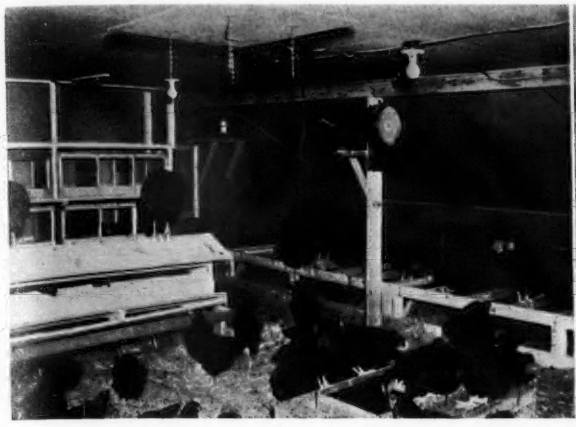


Photo 3 *(Left)* Typical interior showing roosts, nests, instruments, etc. • Photo 4 *(Right)* Direct-air fan ventilation system in house No. 1, showing results of smoke bomb test

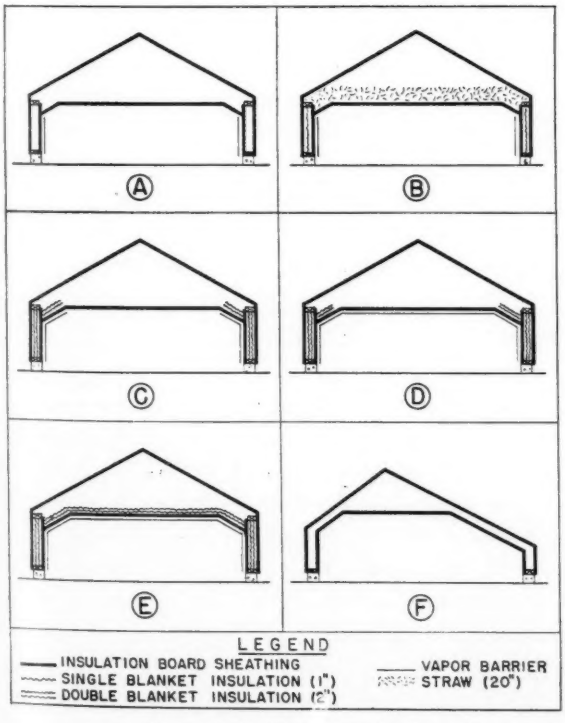
it below that point. The flue extended down to about 12 in above the floor.

Two methods of fan ventilation were used. In both cases a centrifugal-type blower was used to force air into the building, the pressure thus created inside the building being sufficient to provide the necessary flow of air out through wall openings provided with automatic shutters. By the first method used, air was drawn through a wall opening directly from outside and discharged through four 10x1-in openings in a metal duct installed along the north wall at the ceiling. A trough was installed below the duct to intercept and drain away condensation. Photograph 4 is an interior view showing this system. The photograph was made during a smoke bomb test of the air distribution. The fan is located in the northeast corner, near the ceiling, and enclosed with insulation board.

By the second method, the fan is located in the center of the loft directly over a ceiling opening. Air is first drawn into the loft through the louvers in the gable ends. It is then discharged downward into an air distribution box on the ceiling below (Fig. 2). The distribution box provides discharge of air into the building in four directions horizontally along the ceiling. The size of discharge openings was varied to provide desired outlet velocity. For test purposes a tight housing was built around the fan. The housing contained four openings which exactly fit an anemometer with which air volume determinations were made.

One of the outstanding advantages of fan ventilation of this kind was the fact that measurement of the total air volume passing through the building was made possible thereby.

Testing Instruments and Methods. Two or more recording thermometers were located in each building during the testing periods. In every case the temperature-sensitive element of



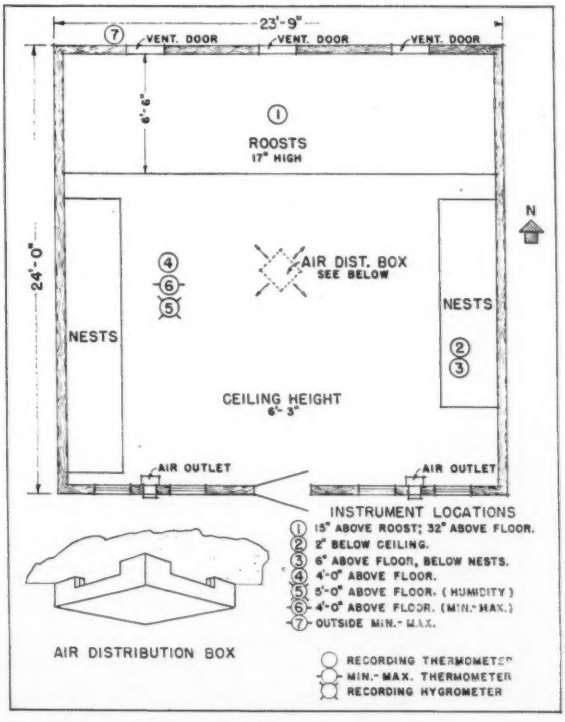


Fig. 1 *(Left)* Types of poultry laying house construction • Fig. 2 *(Right)* General layout of test buildings

one thermograph was located in a standard position about 18 in above the roost and over the center of the roosting area. Another was usually located near the front of the building at least six or eight feet from an outside wall. Records of temperature were also obtained, during some tests, at the ceiling, at the floor, in the loft, and in the air distribution box where

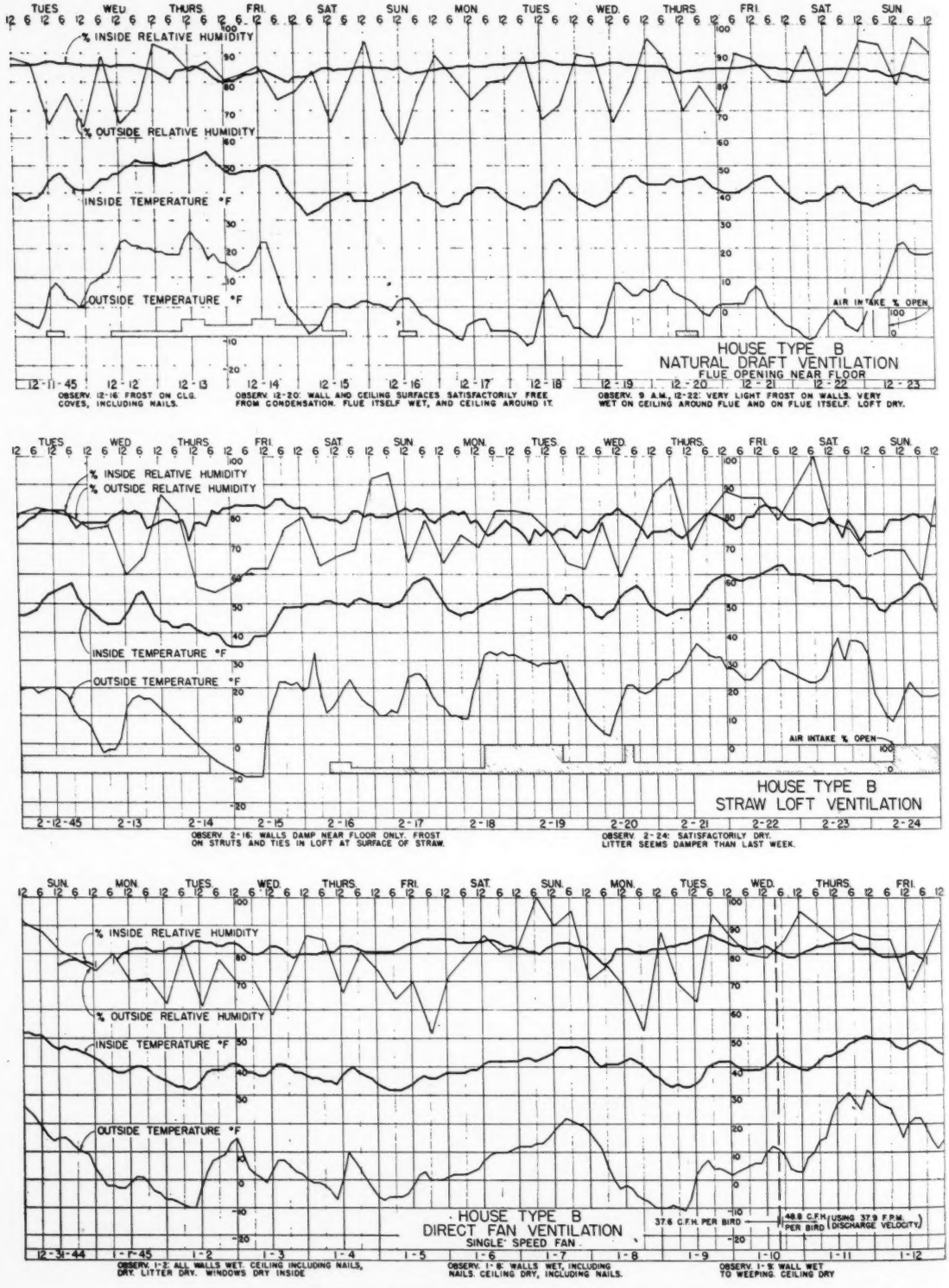

% INSIDE RELATIVE HUMIDITY
% OUTSIDE RELATIVE HUMIDITY
INSIDE TEMPERATURE °F
OUTSIDE TEMPERATURE °F
AIR INTAKE % OPEN
HOUSE TYPE B
NATURAL DRAFT VENTILATION
FLUE OPENING NEAR FLOOR
OBSERV. 12-16: FROST ON CLG. COVES, INCLUDING NAILS.
OBSERV. 12-20: WALL AND CEILING SURFACES SATISFACTORILY FREE FROM CONDENSATION. FLUE ITSELF WET, AND CEILING AROUND IT.
OBSERV. 9 A.M., 12-22: VERY LIGHT FROST ON WALLS. VERY WET ON CEILING AROUND FLUE AND ON FLUE ITSELF. LOFT DRY.
% INSIDE RELATIVE HUMIDITY
% OUTSIDE RELATIVE HUMIDITY
INSIDE TEMPERATURE °F
OUTSIDE TEMPERATURE °F
AIR INTAKE % OPEN
HOUSE TYPE B
STRAW LOFT VENTILATION
OBSERV. 2-16: WALLS DAMP NEAR FLOOR ONLY. FROST ON STRUTS AND TIES IN LOFT AT SURFACE OF STRAW.
OBSERV. 2-24: SATISFACTORILY DRY. LITTER SEEMS DAMPER THAN LAST WEEK.
% INSIDE RELATIVE HUMIDITY
% OUTSIDE RELATIVE HUMIDITY
INSIDE TEMPERATURE °F
OUTSIDE TEMPERATURE °F
HOUSE TYPE B
DIRECT FAN VENTILATION
SINGLE SPEED FAN
37.6 C.F.M. PER BIRD
48.8 C.F.M. (USING 37.9 F.P.M. DISCHARGE VELOCITY) PER BIRD
OBSERV. 1-2: ALL WALLS WET. CEILING INCLUDING NAILS, DRY. LITTER DRY. WINDOWS DRY INSIDE
OBSERV. 1-8: WALLS WET, INCLUDING NAILS. CEILING DRY, INCLUDING NAILS.
OBSERV. 1-11: WALL WET TO WEEPING. CEILING DRY

Fig. 3 Typical performance curves for selected test periods

the record of abrupt temperature changes gave starting and stopping times of the thermostat-operated electric heater, when the latter was used. A recording thermometer was also used to record outside temperature in the immediate vicinity of each test building.

Maximum-minimum thermometers were used in the loft

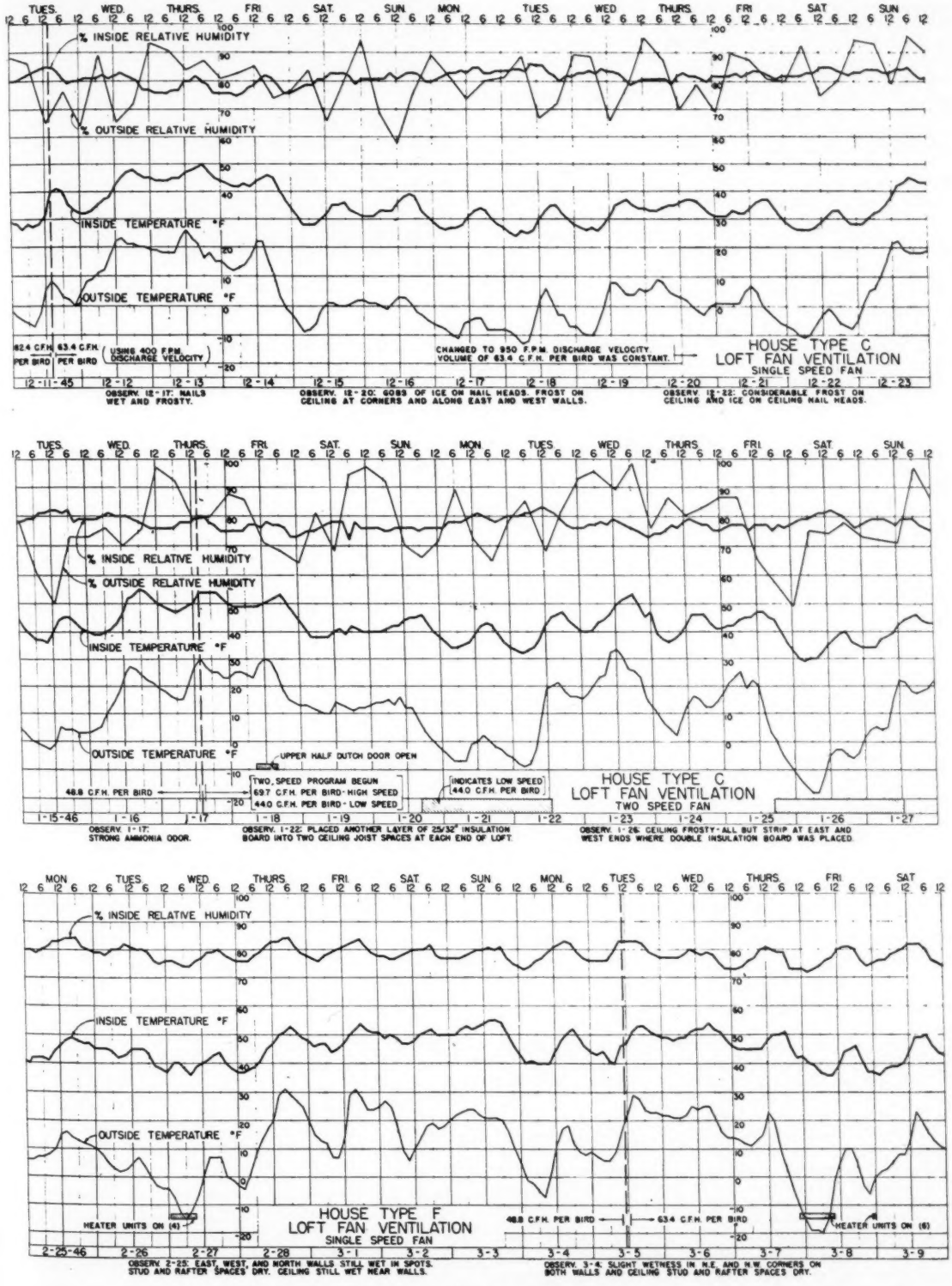

% INSIDE RELATIVE HUMIDITY
% OUTSIDE RELATIVE HUMIDITY
INSIDE TEMPERATURE °F
OUTSIDE TEMPERATURE °F
82.4 C.F.M. PER BIRD
63.4 C.F.M. PER BIRD
USING 400 F.P.M. DISCHARGE VELOCITY
CHANGED TO 950 F.P.M. DISCHARGE VELOCITY. VOLUME OF 63.4 C.F.M. PER BIRD WAS CONSTANT.
HOUSE TYPE C
LOFT FAN VENTILATION
SINGLE SPEED FAN
OBSERV. 12-17: NAILS WET AND FROSTY.
OBSERV. 12-20: GOBS OF ICE ON NAIL HEADS. FROST ON CEILING AT CORNERS AND ALONG EAST AND WEST WALLS.
OBSERV. 12-22: CONSIDERABLE FROST ON CEILING AND ICE ON CEILING NAIL HEADS.
UPPER HALF DUTCH DOOR OPEN
TWO SPEED PROGRAM BEGUN
69.7 C.F.M. PER BIRD-HIGH SPEED
44.0 C.F.M. PER BIRD-LOW SPEED
INDICATES LOW SPEED
44.0 C.F.M. PER BIRD
48.8 C.F.M. PER BIRD
HOUSE TYPE C
LOFT FAN VENTILATION
TWO SPEED FAN
OBSERV. 1-17: STRONG AMMONIA ODOR.
OBSERV. 1-22: PLACED ANOTHER LAYER OF 25/32" INSULATION BOARD INTO TWO CEILING JOIST SPACES AT EACH END OF LOFT.
OBSERV. 1-26: CEILING FROSTY-ALL BUT STRIP AT EAST AND WEST ENDS WHERE DOUBLE INSULATION BOARD WAS PLACED.
HEATER UNITS ON (4)
HOUSE TYPE F
LOFT FAN VENTILATION
SINGLE SPEED FAN
48.8 C.F.M. PER BIRD
63.4 C.F.M. PER BIRD
HEATER UNITS ON (6)
OBSERV. 2-25: EAST, WEST, AND NORTH WALLS STILL WET IN SPOTS. STUD AND RAFTER SPACES DRY. CEILING STILL WET NEAR WALLS.
OBSERV. 3-4: SLIGHT WETNESS IN N.E. AND N.W. CORNERS ON BOTH WALLS AND CEILING STUD AND RAFTER SPACES DRY.

Fig. 3 (continued) Typical performance curves for selected test periods

fan chamber, in the loft proper, in each building, and outside to provide needed data as well as to check the recording instruments and to serve in case of failure of the latter. Weekly readings of maximum-minimum instruments were made, with some read daily for special purposes.

A recording hygrometer was used in all buildings for nearly all tests. Weekly wet and dry bulb determinations were made.

In addition, a Leeds-Northrup eight-point recording thermocouple instrument was installed periodically in houses 1 and 2 for determinations of temperature gradient through wall, ceiling, litter, floor, and soil.

A kilowatt-hour meter was used to record current consumption of fans and heaters.

Air volume measurement (fan ventilation) was by means of Tycos anemometer readings, as above indicated. Changes in rate of ventilation were made by changing fan speed.

Fig. 2 shows approximate location of instruments and other equipment and apparatus in a typical test building.

For all tests, the poultry department of the University of Minnesota provided 175 (average weight, 6 lb) New Hampshire hens, constantly replacing death losses to maintain, as nearly as possible, a constant condition with respect to heat and moisture production.

No attempt was made to relate egg production to environmental conditions.

Limitations of Tests. It is desired, before presenting results and conclusions, to acknowledge the limitations of these investigations both as to scope and also methods of making some of the determinations mentioned in this report. Of great importance is the realization that these are practical determinations under actual field conditions, and a degree of accuracy obtainable in a laboratory cannot be claimed. Comparison of one year's results with those of another, based upon the same outside temperature both years only is subject to the error introduced by differences in wind and sunshine during the two years. It is felt, however, that, in addition to adding to general, practical information on the subject, factors have been uncovered which would not be encountered in a laboratory setup.

Continuation of Investigation. Futher work of this type in actual laying houses would appear to be helpful. Determinations, for example, of ammonia content of the atmosphere in the building, moisture content of the litter under varying conditions, and further attempt to measure heat gained and moisture removal requirement would certainly be worth while, especially to supplement data obtained under more carefully controlled but perhaps less real conditions. The extent to which water vapor passes through a straw loft by direct diffusion needs more study.

It goes without saying that data on the effect upon egg production, fertility, etc., of various environmental conditions are much needed.

Additional work is being done with house Type F using multispeed fan ventilation. It is also desired to test this house with walls and ceiling more heavily insulated.

The two buildings at St. Paul are presently being tested with ventilation by means of a single rectangular opening in the center of the south wall of each.

SUMMARY AND ANALYSIS OF RESULTS

The objectives of this work were originally set down as follows:

1 To find the most economical combination of materials, using the maximum practical amounts of insulation board that will produce satisfactory conditions within the laying house.

2 To accumulate poultry laying house design data.

3 To study the relative advantages of various methods of ventilation.

Significant data such as inside and outside temperatures and humidities, observations of condensation, type and rate of ventilation, heater operation, etc., were plotted and charted for each building and test period, as the data were obtained. Typical sections of these records are shown in Fig. 3. The sections were chosen to be typical of the test period or periods covered in so far as outside temperature and building performance are concerned.

Photo 5 Frost on vapor barrier wrongly installed under interior insulation board

From these records have been taken most of the various data used in Figs. 5 to 9, inclusive. Where inside temperatures have been plotted against outside temperatures, the average of the various inside temperatures which existed each time a certain outside temperature existed was used to plot the curve. This method has the advantage of averaging night and daytime conditions; likewise, variations caused by the lag of inside temperature behind rather rapid decreases and increases of outside temperature are averaged so that the curve probably represents the most accurate estimate possible of equilibrium condition between inside and outside.

The presence of condensation on walls and ceilings was noted simply by observation. No further attempt was made to measure its extent. Generally, it was considered objectionable when present in sufficient quantities to "weep". This criterion is used in reporting the results. The length of a cold spell is of course a variable which has a greater or lesser effect upon formation of condensation. However, the curves of Fig. 3 show that ordinarily not more than about two hours were required for inside temperature to reach equilibrium condition at any point of outside temperature.

The choice of satisfactory house temperature, as the lowest point at which water does not freeze, was made arbitrarily merely for the sake of having a basis for comment and comparison.

House Type A (Insulation board sheathing on walls, ceiling, roof)

Type A was ventilated by fan supplying air directly from outside.

1 Upon removal of a section of unsealed insulation board forming the interior wall surface of house Type A, with mem-

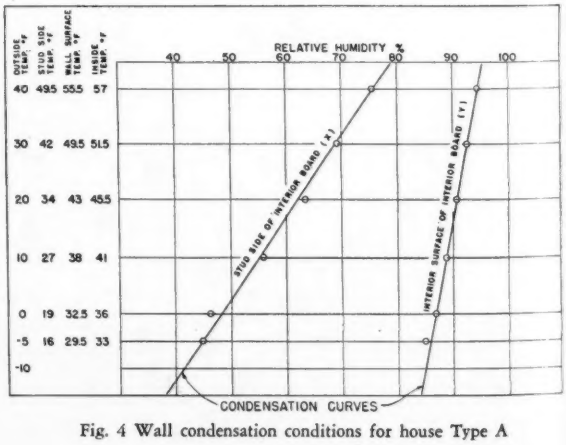


Fig. 4 Wall condensation conditions for house Type A

brane vapor barrier between it and the studs, considerable frost was found to have accumulated on the warm side of the barrier and the insulation board had become wet on the surface toward the barrier. Photograph 5 shows frost on the barrier immediately after removal of a section of the board.

Fig. 4 shows theoretical conditions of temperature and humidity under which dew point would be reached at the point where the vapor barrier was first installed and also on the exposed interior surface where the barrier was finally placed. Each point on curve X represents a condition of temperature (vertical scale, left) and interior relative humidity (horizontal scale, top) which will result in condensation on the barrier at its original location. Likewise curve Y shows conditions at which condensation would occur on the barrier at its new location on the exposed surface of the board. It is obvious that condensation would occur at the original location throughout practically the entire winter period. With interior relative humidity at 75 per cent, for example, the outside temperature would have to be up to about 40F in order to be free of condensation at the original barrier location (curve X). It is evident that for Type A wall construction the vapor barrier must be on the interior surface of the wall, where at 75 per cent relative humidity, for example, no condensation will occur, theoretically, at outside temperatures down to –15F or lower.

During all tests with Type A construction, no vapor barrier was used on the ceiling. No condensation was discovered anywhere in the loft, except for a small frost accumulation on the roof sheathing and rafters near the eaves at and below the straw line, after straw was installed in the loft. No loft condensation was noted in any of the other types of construction tested, regardless of the method of ventilation used.

2 The "interior wall surface" curve (Y) of Fig. 4 indicates that condensation might be expected there when the outside temperature is –15F and the interior relative humidity 84 per cent. From the interior wall surface temperature it is apparent that at this point the condensation would be frost. Actually condensation on surface vapor sealed walls occurred in objectionable quantities (enough to "weep" when melted) at outside temperatures of 0F or lower, even with rather low inside relative humidities and with house temperature kept well above freezing by artificial heat (see Fig. 6, curve a).

Since artificial heat (1600 w) was supplied electrically when the outside temperature was about +5F or less (inside thermostat set at 40F), it follows that the heater was on whenever condensation formed and thus did not help much to prevent it. Cost of operating the heater for the season (1943-44) was 326 kw-hr, which at 3c per kw-hr would be $9.78. (This is an estimate based on the rate of use during the greater part of the season.) Minimum outside temperature during this 1943-44 season was –13F, which was unusually high. Thus the cost would probably have been somewhat higher for a more normal winter. Regardless of this the use of artificial heat with this type of construction appears not to be justified because of the condensation experienced.

Without artificial heat, water-freezing temperatures occurred with Type A construction at outside temperatures of from –5 to –10F.

Litter (wood shavings) was changed about every three to five weeks and became objectionably wet quite rapidly.

3 The addition of 20 in of tramped loose straw to the loft of house Type A increased the inside house temperature about 5 deg. This was reduced to 2 to 3 deg after the straw had been installed for about nine months. Apparently this was due to settling. Fig. 5 shows temperatures in the loft of Type A house before and (Type B) after use of straw. Effect of the straw in reducing heat loss from the house to the loft is indicated thereby. However, objectionable wall wetness can still be expected with Type A construction at about 0F outside temperature.

4 Summertime temperature readings in house Type A showed that it was possible to maintain inside house temperatures equal to or lower than outside temperatures with the latter ranging from 81 to 94F. These trials were made with the entire flock confined and with the four windows, three ventilating doors under the roosts, and the entrance door open and screened. Minimum wind velocities of 5 to 10 mph prevailed during most of the tests.

Trials were also made using fan ventilation supplying air directly from the outside at the rate of 91 cfh (cubic feet per hour) per bird. While the maximum outside temperature existing during this test was only 84F, results generally showed that there was no advantage in operating the fan.

5 House No. 3, having heat-losing surface and enclosed space reduced from that of houses Nos. 1 and 2 by 4.3 per cent and 8.0 per cent, respectively, maintained inside temperatures about 2F higher than house No. 1 at the same outside temperature. (See Fig. 6, curves a and b.) This advantage is small but house No. 3 requires 272 less board feet of lumber and 248 less square feet of wall, roof, and ceiling sheathing than house No. 1. Based on May 20, 1946, prices at Minneapolis, this means a saving of $34 in material. About 30 per cent less paint would be required for No. 3 house. Labor of construction is probably the same for the two buildings.

House Type B (Type A with single blanket added to walls and straw in loft)

6 House Type B maintained inside temperatures of from 32 to 36F, (with three methods of ventilation), safely above water-freezing point, at an outside temperature of about –10F.

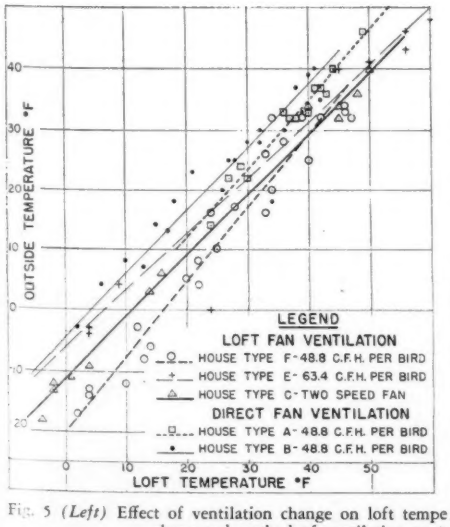
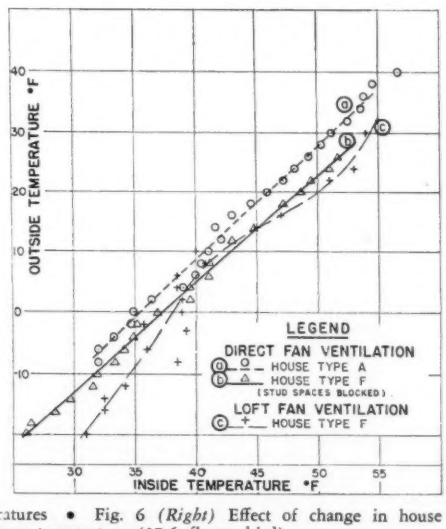

OUTSIDE TEMPERATURE °F
LOFT TEMPERATURE °F
LEGEND
LOFT FAN VENTILATION
HOUSE TYPE F-48.8 C.F.M. PER BIRD
HOUSE TYPE E-63.4 C.F.M. PER BIRD
HOUSE TYPE C-TWO SPEED FAN
DIRECT FAN VENTILATION
HOUSE TYPE A-48.8 C.F.M. PER BIRD
HOUSE TYPE B-48.8 C.F.M. PER BIRD

Fig. 5 *(Left)* Effect of ventilation change on loft temperatures • Fig. 6 *(Right)* Effect of change in house shape and method of ventilation on house temperature (37.6 cfh per bird)



At this outside temperature condensation on walls was noticeable and at the point of becoming objectionable. Fig. 7 shows house temperatures for Type B with various methods of ventilation. Outside temperatures were not low enough to compare accurately house temperatures at the two rates of fan ventilation.

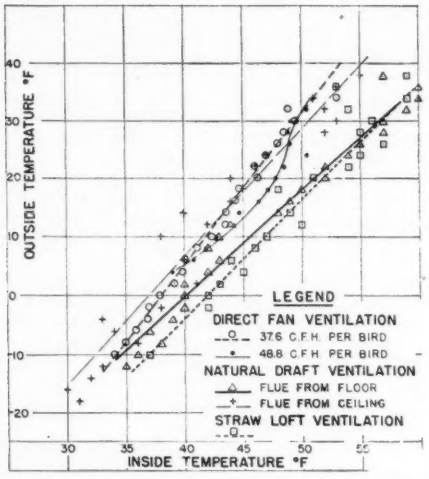


Fig. 7 Effect of ventilation change on house temperature in house Type B

The litter (wood shavings) became too wet in house Type B until the built-up method was used, when it remained very satisfactory. (The built-up litter is a relatively deep accumulation resulting from frequent additions of new litter without removal of the old.)

7 Use of natural-draft flue and straw loft methods of ventilation in house Type B generally kept a somewhat higher temperature in the building than did ventilation by constant speed fan (Fig. 7). This is probably due to the operator's tendency to restrict air flow, during cold weather, beyond the level provided by the fan. Generally house temperatures were undesirably high in mild weather when flue ventilation was used. This was not so noticeable with straw loft and fan ventilation.

Other things equal, and with the same operator adjusting the air inlet, ceiling-level flue operation left the building from 3½ to 4½ deg colder than floor-level flue or straw loft operation, but the ceiling-level flue provided lower relative humidities than the floor-level flue.

Of the three methods of ventilation (ceiling-level flue, floor-level flue, and straw loft) the straw loft method provided the greatest degree of dryness, relative humidities during the entire period being very satisfactory.

With all three methods of ventilation, better control of conditions was obtained more easily by use of a single air inlet on the east wall than by use of two.

House Types C and D (Type A with double blanket added to walls only)

8 House Types C and D were ventilated by means of a loft fan. Fig. 8, curves a, b, and c, shows house temperatures. Water-freezing temperatures in the building were reached at about −10 F outside with ventilation rate constant at 63.4 cfh per bird. This minimum rate of ventilation was necessary to minimize temperature variation and odors during much of the milder winter weather. With a two-speed fan (69.7 cfh high, 44.0 cfh low) satisfactory conditions (above water freezing) were maintained in all outside temperatures down to −18 F.

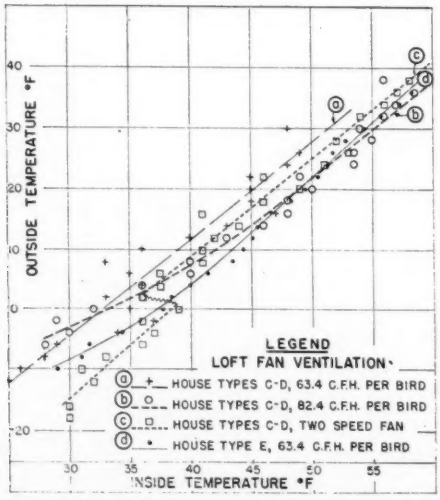
While the ventilation rate of 82.4 cfh per bird (curve b, Fig. 8) is unnecessarily high except for mild weather, it is interesting to note that, for example, at −3 F outside temperature, house temperatures for ventilation rates of 63.4 cfh and 82.4 cfh are about equal at 32 F; at higher outside temperatures the higher rate of ventilation actually provided the warmer building, while at lower outside temperatures (below −3 F) the lower rate (63.4 cfh) gave higher house temperatures.

In house Type D condensation on the ceiling was very heavy and objectionable. In C, however, at all rates of ventilation, heavy condensation (sometimes ice) occurred on ceiling nail heads only. A slight but not objectionable amount of condensation was noted on walls at stud and plate locations (worst in corners). Some condensation on the ceiling adjacent to east and west walls was eliminated by using an extra layer of 25/32-in insulation board in the first two ceiling joist spaces at each end of the building.

In Types C and D, as in B, litter became too wet until the built-up method was used.

House Type E (Type A with double blanket added to walls and ceiling)

9 House Type E was ventilated by means of a loft fan. Fig. 8, curve d, shows house temperatures. This type performed satisfactorily at a ventilation rate of 63.4 cfh per bird, but water-freezing house temperatures were reached at about −10 F outside, the same as in Types C and D. It is probable that with a multispeed fan, as used in Type C, Type E would also be kept above the water-freezing mark at about −18 F out-


OUTSIDE TEMPERATURE °F
INSIDE TEMPERATURE °F
LEGEND
LOFT FAN VENTILATION
HOUSE TYPES C-D, 63.4 C.F.H. PER BIRD
HOUSE TYPES C-D, 82.4 C.F.H. PER BIRD
HOUSE TYPES C-D, TWO SPEED FAN
HOUSE TYPE E, 63.4 C.F.H. PER BIRD

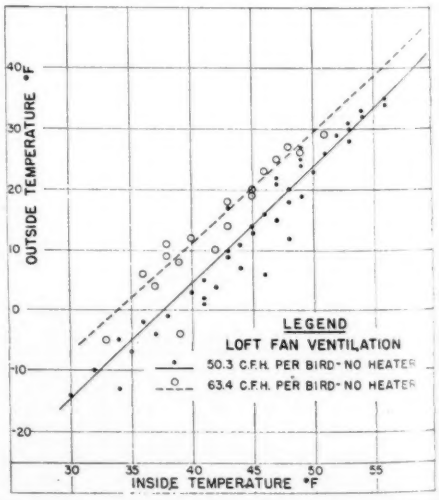


Fig. 8 *(Left)* Effect of ventilation change on house temperature in house Types C, D, and E • Fig. 9 *(Right)* Effect of ventilation change on house temperature in house Type F

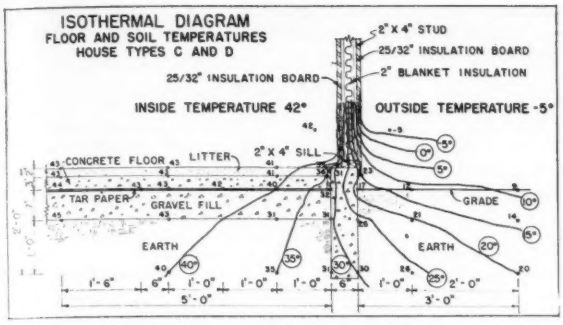


Fig. 10 Isothermal diagram of floor and soil temperatures in house Types C and D

side temperature. Since this performance is about the same as that of Type C, it appears that the heat saving effected by the additional ceiling insulation in Type E is balanced in Type C by the greater rate of heat regained from the loft by the ventilating fan.

In Type E the litter became too wet until the built-up method was used.

Minor condensation occurred on a few wall and ceiling surfaces, as it did on the walls of Types C and D. It was not objectionable and apparently would not be so at outside temperatures down to –18 to –20 F.

House Type F (Type A without vapor barriers and with open stud spaces; low front and rear walls)

10 Fig. 6, curves b and c, offer opportunity to compare house temperatures when house No. 3 was operated as Type A with fan supplying air directly from outside (curve b) and when it was operated as Type F with loft fan and open stud spaces (curve c). These curves show a temperature advantage of about 4 deg for the Type F arrangement when the outside temperature was about –20 F. These figures were obtained at a low rate of ventilation (37.6 cfh per bird), and higher rates subsequently showed even greater advantages to house temperature of the Type F arrangement. The advantage is less at higher outside temperatures. This higher house temperature is obviously due to heat regain in the form of increase in air supply temperature.

The curves of Fig. 5, showing loft temperatures with various construction and ventilation arrangements, indicate the advantage to air supply temperature in cold weather of Type F over all other arrangements tried. For practical purposes, the loft temperature (taken near the fan) is the temperature of the air supplied to the building. Note that the Type F loft was warmer than Type A in spite of the fact that (1) the entire volume of ventilating air was being drawn through the Type F loft and (2) the horizontal ceiling surface of Type F was smaller than that of Type A. This is apparently due to the gain of heat in the loft from the open stud spaces of Type F.

11 In house Type F roof sheathing and the inside surface of exterior wall sheathing remained free from objectionable frost and condensation when the building was adequately ventilated. By periodic examination of a few "check" stud spaces kept closed, very heavy frost accumulation for prolonged periods was noted on inside surface of exterior sheathing in the closed spaces.

12 House Type F, without artificial heat and using only loft fan ventilation, became objectionably wet on walls and parts of the ceiling while using the lower rates (37.6 and 48.8 cfh per bird) of ventilation. Use of artificial heat did not remedy this. However, at a ventilation rate of 63.4 cfh per bird and without artificial heat, satisfactory dryness (except in extreme northeast and northwest corners of walls and on ceiling nail heads) and house temperatures above the water-freezing point resulted when the outside temperature was approximately –15 F. Fig. 9 shows this performance.

At this rate of ventilation (63.4 cfh) a 1500-w heater, controlled from fan inlet temperature, while permitting the maintenance of satisfactory conditions of warmth and dryness (as above) at outside temperatures of about –20 F, nevertheless also permitted the house temperature to drop to 24 F when the outside was –28 F. Thus the actual gain from the heater seems to be slight. Cost of operating the heater for a season (November to March) was approximately 1,000 kw-hr, which at 3c per kw-hr would be $30.

It might be assumed that satisfactory performance (except for possible objection to frost and ice on ceiling nail heads) could be obtained at all outside temperatures down to –15 F, if the stud spaces at the corners of the building were heavily insulated and vapor-sealed. It is possible that an additional small amount of insulation would be needed between ceiling joists at the east and west ends of building. It appears also that good conditions might be maintained at an outside temperature lower than –15 F if a multispeed fan was used.

Litter was changed too frequently (usually weekly) to observe accurately the tendency to become wet.

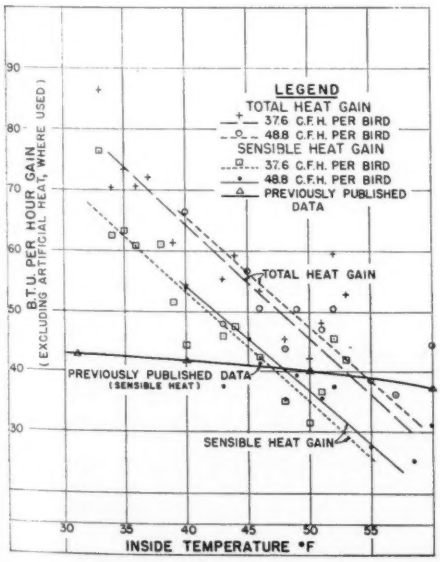
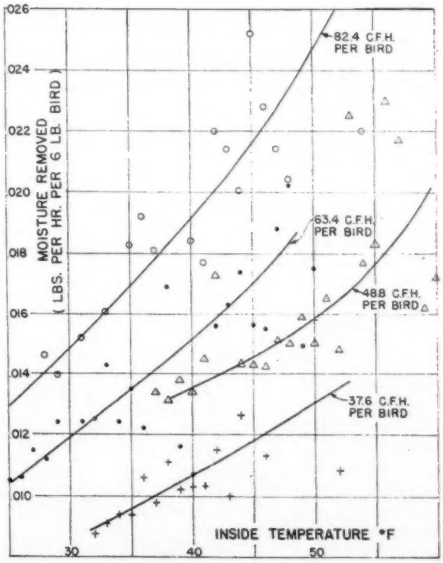


Fig. 11 *(Left)* Heat gain per bird computed from estimated heat losses at various temperature levels (175 6-lb hens used in tests) • Fig. 12 *(Right)* Moisture removed at various rates of ventilation


82.4 C.F.H. PER BIRD
63.4 C.F.H. PER BIRD
48.8 C.F.H. PER BIRD
37.6 C.F.H. PER BIRD
MOISTURE REMOVED (LBS. PER HR. PER 6 LB. BIRD)
INSIDE TEMPERATURE °F

It was shown that the character of the condensing surface is an important factor in the formation of condensation. The surface of uncoated insulation board may be free from visible condensation under conditions of temperature and humidity that would have caused considerable condensation on a vapor-sealing surface.

Supplementary Studies (Fan ventilation, soil and floor temperatures, heat and moisture gains)

13 When fan ventilation was used in any type house, without artificial heat, temperatures at or near the ceiling of the building were as much as 5 deg lower than at the floor.

No drafts that might be considered objectionable were noticed in the region occupied by the birds. Smoke bomb tests indicated that an extremely low air velocity existed in the lower part of the building.

Temperature variation in the various buildings, while being ventilated by the various methods, may be studied in Fig. 3.

Two-speed fan operation appeared to offer advantages over constant speed while requiring only a minimum of manual attention. During a period of use of a two-speed fan from January 17 to March 10 only four periods of low-speed operation were necessary. The total low-speed operating time was approximately seven days. Fig. 3 shows two-speed operation in house Type C. If the two-speed arrangement had been used for the entire 1945-46 season, four additional periods of low-speed operation would have been required, making a total of eight periods and about 23 days for the season.

Meter readings of current consumption of the 1/6-hp fan motor used in house No. 1 (Type A) during the 1943-44 season averaged approximately 13 kw-hr per week, which, for the 16 weeks (November 22 to March 13) of continuous operation probably required in areas of similar climate, would be 208 kw-hr. At a 3c rate the seasonal cost would be $6.24.

14 A study of soil, floor, and litter temperatures indicates that any appreciable difference between indoor air temperature and floor temperature is confined to that portion of the floor within 12 in of the outside walls (see Fig. 10). The results of this study seem to suggest that low floor temperature is not a major factor contributing toward wet litter as a result of condensation; indicated also is the fact that heat loss through the floor from a building of the types tested is certainly not appreciable, and could, therefore, for practical purposes, be ignored in making heat loss calculations. It appears that during cold spells of short duration there might even be some heat gain through the floor in the center portion of the building.

15 In order to explore the possibilities of gaining additional valuable design information from these studies, careful estimates of total heat loss (by ventilation and conduction) from the building (Type A) were made. This heat loss was assumed to be equal to all heat gains. Heat gain figures (deducting artificial heat added) are shown in Fig. 11 on a "per hen" basis. Total heat, indicated by the broken line curves, includes gain in latent heat of vaporization as well as sensible heat. The solid line curves indicate gains in sensible heat only which is actually the only usable heat when there is no condensation and all of the latent heat thus escapes with the vapor removed.

It is interesting to note how much more heat is apparently available in the lower range of house temperatures than previously published laboratory figures would indicate. It is thought probable that this is partly the result of a gain of some latent heat due to condensation during the colder weather; also probably the result of the gain of some heat through the floor.

While the data of Fig. 11 are subject to errors in estimating heat losses, etc., all of the sources of heat gain in the poultry house are automatically included and at least the slope of the curves may therefore be of some significance.

16 The amount of moisture actually removed from test buildings Nos. 1 and 2 was calculated by use of indoor and outdoor temperature and relative humidity data. These data are plotted in Fig. 12 where the number of pounds of moisture removed per bird is shown for various house temperature conditions and various rates of ventilation. It is interesting to note that, when ventilating at the rate of 63.4 cfh per hen, which is the rate that gave most satisfactory over-all results, moisture was removed at approximately three times the rate at which, according to available published data, it was respired by the birds.

CONCLUSIONS

1 *Type A* construction is satisfactorily warm and dry (free from objectionable wall and ceiling condensation) in weather down to about 0 F. Weeping occurs on walls in colder weather. Use of straw in the loft and use of artificial heat both make the building warmer but do not appreciably diminish wall condensation.

With Type A construction the wall vapor barrier should be on the interior exposed surface.

Type A construction with all windows and doors open will, generally, maintain temperatures in warm weather no higher than outside temperatures.

Gains can be made in house warmth (about 2 deg) and reduction of material cost by reducing front and rear wall heights to a minimum.

2 *Type B* construction is satisfactorily warm and dry in weather down to about −10 F. Weeping occurs on walls in colder weather.

Fan, natural draft flue, and straw loft are all effective means of ventilation. Straw loft provides lowest relative humidity; floor-level flue provides the warmest house (too warm in mild weather); ceiling-level flue provides colder house than floor-level flue, but also lower relative humidity.

3 *Type C* construction is satisfactorily warm and dry in weather down to −10 F with use of constant-speed fan ventilation and down to −18 F with two-speed fan. Water-freezing temperatures occur in the building during colder weather.

Single thickness 25/32-in insulation board ceiling must have no vapor barrier.

Type C performance in weather mentioned above results in frost and ice formation on ceiling nail heads which might be objectionable.

4 *Type D* was not satisfactory because of condensation on the ceiling.

5 *Type E* construction is satisfactorily warm and dry in weather down to −10 F with use of constant-speed fan ventilation. Water-freezing temperatures occur in the building during colder weather.

With loft-fan ventilation there appears to be little or no value in the vapor barrier and supplementary (to insulation board) insulation in the ceiling which characterizes Type E as distinguished from Type C.

6 *Type F* construction is satisfactorily warm and dry, without artificial heat, in weather down to −15 F with use of constant-speed fan ventilation and probably down to lower temperature with multispeed fan. For such satisfactory performance corner stud spaces should probably be heavily insulated and vapor-sealed.

Type F performance in weather mentioned above results in frost and ice formation on ceiling nail heads which might be objectionable.

Type F arrangement provides an appreciably warmer house than Type A.

Wall and rafter spaces (wall of two layers of 25/32-in insulation board) open to the loft may be kept satisfactorily free from condensation without use of a vapor barrier.

Condensation may occur on a vapor-sealed surface when conditions are such that an uncoated insulation board surface remains dry.

7 *Loft-fan ventilation* appears to have several distinct advantages. Multispeed operation improves performance. Approximate current consumption of single-speed fan motor in house Type A was 13 kw-hr per week.

8 *Floor and litter temperatures* do not appear to be a major factor in causing wetting of litter.

9 *Natural usable heat gain* in a laying house needs much more careful study. It seems probable that the variation of heat gain with house temperature is greater than has been believed.

10 *Moisture removal* from a laying house appears to be required at a rate at least equal to three times that of moisture respiration by the hens, as indicated by published data.

Spreader Room Added to Dairy Barns

TO THE EDITOR:

WE ARE attempting to educate farmers into the use of what we call a spreader room. Occasionally, in various parts of the country, we have known of farmers having a room attached to their barn to house their spreader. Such rooms served merely as a storage space for the spreader and served no real practical purpose other than this. The accompanying pictures show our spreader room as used in conjunction with a mechanical barn cleaner. The spreader is parked in this convenient, small, insulated room under the discharge end of a barn cleaner elevator. This provides a definite place for the tractor and spreader, avoiding the unsanitary and inconvenient placing of this equipment in the barn alley, or leaving it out in the mud, rain, snow, and other adverse weather conditions. The use of a flat elevator provides a sanitary conveying system from the gutter to the spreader. This flat elevator, and the separate attached room with concrete floor for housing the spreader, we believe, will mark a new advance in providing more sanitation in and around the dairy barn.

Promoting spreader rooms, to our knowledge, is unique with our organization. We have demonstrated our idea to the county agents, power utilities, universities and health department officials. They have expressed a decided liking for it and are actively supporting us in promoting this feature.

We have nothing to gain financially in talking about spreader rooms. The idea came to the writer in connection wiith his investigation of mechanical barn cleaners. Unsanitary manure piles outside of most barns, filthy spreaders standing in otherwise well-cleaned barns, together with the extra work and fly conditions caused by such practices, led me to work out the spreader room shown in the pictures. These rooms became practical with the coming of mechanical barn cleaners.

We feel that our responsibility to good farming practice goes beyond the mere sale of equipment. Because of this, we have set up an organization in which we not only sell and install equipment, but also supervise and engineer that equipment to each farmer's own peculiar requirements. Possibly, we are taking our work too seriously but it is about time that organizations such as ours were set up to give the farmer some help. Universities and county agents are active in educational and promotional ideas for better farming but are handicapped from the very nature of their work in actively selling and installing those ideas for individual farmers. It is our purpose to carry on where they leave off.

This work on spreader rooms leads to other revolutionary practices, which now can fit into this program. Therefore, we are actively studying and promoting such things as soil conservation, storage of manure liquids to retain their value until ready to put on the field, and narrowing new barns to reduce the size and aid in proper ventilation, center feeding alleys, etc. In fact, there seems to be no end to what we can accomplish with proper installations of mechanical barn cleaners.

We are also vitally interested in promoting mechanical hay drying to conserve the protein which we are now growing and destroying because of our inability to harvest our crops at the proper time. Corn drying is another field in which we can help the farmer produce larger yields for the same amount of labor and seed by growing later corn and assuring the success of saving the harvest by making it possible to dry it properly in spite of unpredictable short growing seasons which we have experienced and cannot control.

The work does have a lot of romance and has become more interesting as we get further into our program. It is our belief that we are building up a valuable service to the farmers in the three states in which we are working. Also this cannot help but lead to better farming practices. The prestige and success of our work, if properly continued, should spread out and show its influence even on a national scale.

R. W. WESTERBERG
Farm Engineering Sales, Inc.

RESEARCH NOTES

A.S.A.E. members and friends are invited to supply, for publication under this heading, brief news notes and reports on research activities of special agricultural engineering interest, whether of federal or state agencies or of manufacturing and service organizations. This may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Mich.

BY THE middle of July the corn crop appeared to be about two weeks later than usual in most areas. Even with generally good growing weather the rest of the summer farmers expect to harvest much soft corn this fall. Almost no research data have been available on the effects of an early frost on the soft-corn situation. It has been supposed that in addition to reducing quantity and quality an early frost might slow down the rate of drying of corn standing in the field and so further complicate the problem of high moisture content with its hazard of spoilage in storage.

J. L. Schmidt, assistant agricultural engineer, Division of Farm Buildings and Rural Housing, USDA, has just reported a study he made in cooperation with W. V. Hukill, C. K. Shedd, and B. M. Stahl on the effect of freezing on the drying rate of ear corn on the stalk. The investigation, made at Ames during the early fall of 1946, also included the effects of stripping the leaves from the stalks and of breaking off the ears and leaving them to dry in the field under the same conditions.

Four rows of corn about 100 ft long were selected for the study. During the last week in September this corn had a kernel moisture content of about 51 per cent. The stalks and leaves were still green, showing no sign of drying, and the ears had left the milk stage only a week or so earlier.

Stalks and ears in the first row were untouched and left as check. Stalks and ears in the second row were frozen, a few at a time, by means of a box 10 ft long, 8 ft high, and 2 ft wide, open at the bottom and with replaceable ends, which contained dry ice. Air temperatures of 20 to 25 F were maintained immediately around the corn for 20 to 30 min. A day or two later the leaves dried and curled, but it was doubtful whether all the stalks were killed by the artificially induced freeze.

Stalks in the third row were stripped of leaves but ears were left untouched. Ears in the fourth row were broken from the stalks at the shank and retied to the stalks. From 10 to 20 sample ears were taken from each of these rows once a week and later once every two weeks—six samples per row in all. The first natural killing frost was November 12, and the study extended through November 25.

The principal test on each sample was kernel moisture content. To determine the effects on grain quality, test weight was taken for every sample after it had been oven-dried to 10 per cent moisture content. Increasing test weights for successive samples from the check row show the increase in quality of the corn as it matured naturally. Growth did not stop altogether after freezing or stripping the leaves, as it did after breaking the ears from the stalk, but it was slower. Corn so treated never reached as high a test weight as the check corn.

Of most interest, however, is the fact that the frozen corn dried more rapidly than the untouched corn—about as fast as corn broken from the stalk and left out for exposure. Stripping the leaves from the corn plant also hastened the drying rate but not to the same extent as freezing. The disadvantage of loss in yield and quality from freezing may be offset in some seasons by the faster drying rate and the consequent safer storage from early harvesting.

* * * *

The adverse conditions for corn storage this year place new emphasis on the effect of foreign material upon the storage of ear corn. In the fall of 1945 USDA agricultural engineers at Ames, Iowa, set up an experiment to test the relative moisture content, kernel damage, and surface mold of ear corn stored with varying amounts of loose shelled corn, husks, and other debris. *(Continued on page 368)*

(Left) Spreader room addition to dairy barn • *(Right)* Spreader in room under delivery end of elevator

NEWS SECTION

Corn Conditioning Conference

THE American Society of Agricultural Engineers, in cooperation with the USDA Bureau of Plant Industry, Soils, and Agricultural Engineering, state agricultural experiment stations, and interested manufacturers, sponsored the "Conference on Conditioning the 1947 Corn Crop" held at the Congress Hotel, Chicago, July 21. No advance publicity on the meeting was given out, except to some one hundred or more specialists and others in key positions to make definite contributions to such a conference. Nearly two hundred persons attended, and an interesting program was presented.

The formal papers on the program were as follows: Dr. S. R. Miles, Purdue University agronomist, discussed saving this year's soft corn. The subject of a talk by E. A. Ellison, U. S. Department of Agriculture, dealt with soft corn problem areas. Soft corn as seen by the processor was discussed by R. C. Wagner of Clinton Industries, Inc. Wallace Ashby, USDA ag engineer, discussed conditioning of corn in storage, preliminary to a joint paper by D. G. Carter, University of Illinois ag engineer, and Leo E. Holman, another USDA ag engineer, on results of corn drying studies. H. J. Barre, Purdue University ag engineer, talked on corn drying by mechanical means. The use of hay-drying equipment for conditioning corn was discussed by R. C. Miller of Ohio State University, and F. D. Yung, University of Nebraska ag engineer, presented a brief report on corn drying experience in Nebraska. W. V. Hukill, USDA ag engineer, gave a paper on factors in designing corn driers, and the subject of safety requirements in conditioning corn was discussed by C. K. Shedd, another USDA ag engineer.

Following these papers several manufacturers' representatives discussed available corn conditioning equipment. The papers presented were summarized by C. E. Frudden, consulting engineer, Allis-Chalmers Mfg. Co., and at the noon luncheon Hon. N. E. Dodd, Under Secretary of Agriculture, addressed the group on the effect of the corn situation on world food needs.

Following the conference a committee of agricultural engineers appointed by A.S.A.E. President Geo. A. Rietz devoted the evening to drafting the recommendations for the mechanical conditioning of corn found elsewhere in this issue of AGRICULTURAL ENGINEERING.

Research Round Table

THE Committee on Research of the American Society of Agricultural Engineers held an open round-table meeting during the Society's annual meeting in June. The Committee report was presented in sections corresponding to its three subcommittees. The first, on major research projects, cited a mimeograph, titled "Opportunity for Agricultural Engineering Research," circulated by the subcommittee chairman in August, 1946, to all state agricultural experiment stations which have agricultural engineers on their staffs. This mimeograph outlined the scope and intent of the Flannagan-Hope Act. A member of the Committee explained the present interpretations of the intent of the Act and the present status of appropriations to support it, and it was pointed out that there is still some question as to the apportionment to marketing hinging on the word "authorized," when the total actual appropriations are less than originally authorized. Attention was called to the scope of the "marketing" research, which is generally taken to include any problem after harvesting, but is indistinct in some borderline cases of processing.

A member of the Subcommittee on Coordination of Research discussed the 9 b 3 funds for interstate regional cooperative research. He explained the necessity for designating a leader state and outlined the method of writing a comprehensive project to include the gathering together of existing information as a foundation for further field research. As to methods of achieving real cooperation, the research workers in various states are expected to agree on certain factors as *standards* of acceptance and also on certain *techniques* of measurements so that all work can be interpreted in the same manner. Each state is of course free to use other standards and techniques, but these should be in addition to those agreed upon for reporting cooperative work. There was further comment on joint agreement as to division of effort, and a positive statement that travel expense is plainly authorized under the Flannagan-Hope Act to organize the results of cooperative research.

What started out as a subcommittee report on technique and publication eventually evolved as one of the addresses at the general session of the meeting, entitled "Research Procedures for Cooperative Projects with Limited Personnel," delivered by the general chairman of the Committee.

In the course of the general discussion of research activity, John A. Nicholas of Pennsylvania State College raised the question as to the failure of the Society to adopt standards in the field of refrigeration which the American Society of Refrigerating Engineers had readily accepted and adopted. Mr. Nicholas had also received a request from the Safety Committee of the American Institute of Electrical Engineers that the A.S.A.E. set up standards for electric fencing based on the effect of electric shock on various farm animals.

Following considerable discussion of standardization activity, it was voted to recommend to the Council of the Society that the Committee on Research be authorized to set up subcommittees on standardization and to process standards according to the by-laws of the Society. As to research needed on electric fencing, it was agreed that the Committee should suggest to the Agricultural Research Administration (USDA) that it receive favorably any proposed research necessary to establish A.S.A.E. standards for electric fencing based on the sensitivity of various animals to electric shock. Reported by F. A. Brooks, chairman, Committee on Research (1946-47).

A.S.A.E. Meetings Calendar

October 23 and 24—PACIFIC NORTHWEST SECTION, Davenport Hotel, Spokane, Wash.

December 15 to 18—FALL MEETING, Stevens Hotel, Chicago.

June 20 to 23—ANNUAL MEETING, Multnomah Hotel, Portland, Oregon.

Purdue Conference on Farm Work Simplification

THE farm work simplification committees of the American Farm Economic Association and the American Society of Agricultural Engineers met at Purdue University, June 16 to 19, to begin the organization of a manual of work simplification and to develop closer cooperation between the two professional organizations. The conference was arranged by Dr. Lowell S. Hardin and Dr. E. C. Young of Purdue University.

The conference opened with a discussion of the functions of management and engineering in the field of work simplification, followed by short reports of the work currently under way at the institutions represented by members of both committees. Considerable time was spent in discussion of the projects now active and on ways and means whereby engineers and economists could work together in an analysis of the problems. There was also discussion of methods of using the results of work simplification research in extension and resident teaching, and on the basic training of research workers in this field.

The last sessions of the conference were devoted to developing an outline of the proposed manual of farm work simplification. Dr. L. M. Vaughan, of the Labor Utilization office of the Extension Farm Labor Program, and executive secretary of the A.F.E.A. farm work simplification committee is spending the next several months working on the subject matter. Plans are now under way for the two committees to meet again at a later date to continue work on the manual.

The A.S.A.E. Committee on Farm Work Simplification was represented at the conference by Paul R. Hoff (chairman), H. L. Garver, W. D. Hemker, B. G. Perkins, I. D. Mayer, and D. C. Sprague.

Nominations for A.S.A.E. Medal Awards

IN ACCORD with the rules governing the award of the John Deere and Cyrus Hall McCormick Gold Medals, the Jury of Awards of the American Society of Agricultural Engineers will receive from members of the Society, up to November 1, nominations of candidates for the 1948 awards of these two medals.

Members of the Society nominating candidates for either award are requested to keep in mind the purposes of each medal and make their nominations accordingly. The John Deere Medal is awarded for "distinguished achievement in the application of science and art to the soil," which citation is interpreted to cover more than a mechanistic concept of engineering, and to include chemistry, physics, biology, and any other science and art involving the soil, the "application" being acceptable to "evaluation by the engineering criteria of practicality and economic advantage."

The Cyrus Hall McCormick Medal is awarded "for exceptional and meritorious achievements of a continuing career or to any single item of engineering achievement, and to apply equally to all special fields and types of engineering in agriculture."

The Jury of Awards desires that members of the Society consider it their duty and obligation to give serious thought to the matter and nominate for either or each of these awards *(Continued on page 366)*

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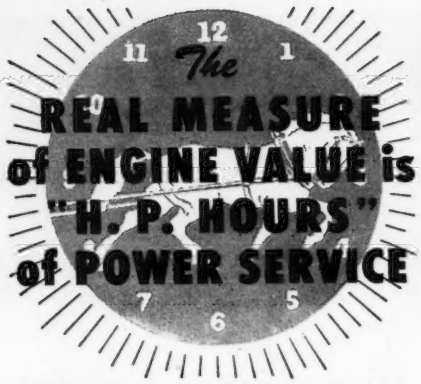

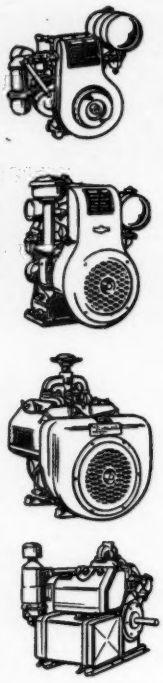

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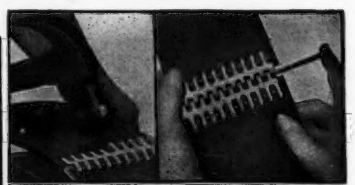
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NEWS SECTION

(Continued from page 364)

the men they believe to be most worthy of the honor. Each nomination must be accompanied by a statement of the reasons for nominating a candidate and qualifications of the nominee, including his training, experience, contributions to the field of agriculture, a bibliography of his published writings, and any further information which might be useful to the Jury in its deliberations.

The Jury will accept and consider nominations received on or before November 1, and these nominations should be addressed directly to the Secretary of the Society at St. Joseph, Michigan. The Secretary will supply on request a standard set of instructions for preparing information in support of nominees for the Society's gold medal awards; in fact, it is important that these instructions be followed in preparing material on behalf of any nominee.

Roberts New Washington A-E Head

JUNE ROBERTS is the new head of the agricultural engineering department at Washington State College, effective July 1.

Mr. Roberts joined the institution's agricultural engineering staff in 1940, and recently returned to the department after four years of service in the U. S. Naval Reserves during the war. He is a graduate in agricultural engineering of Kansas State College, and for a time following graduation was on the agricultural engineering staff at that institution. Mr. Roberts succeeds L. J. Smith who is relinquishing his duties as head of the department, at his own request, but who will continue as a member of the staff doing special teaching and research in the field of farm structures.

The department of agricultural engineering is moving into a newly completed two-story building which will greatly facilitate the work of the staff in meeting the new demands upon it.

Orval French to Cornell

ORVAL C. FRENCH has resigned as a member of the agricultural engineering staff of the University of California, to accept appointment as head of the agricultural engineering department at Cornell University effective September 1st. He will succeed B. B. Robb who is retiring from administrative duties as head of the department for reasons of health, but will continue to engage in teaching and research work in the department.

Mr. French is a native of Kansas and received both his bachelor's and master's degrees in agricultural engineering at Kansas State College. He was on leave of absence from 1942 to 1945, from his duties at the University of California, to serve in special war work with the Radiation Laboratory of the University of California as mechanical research and patent engineer.

"Mow Drying of Hay" Reprint

THE American Society of Agricultural Engineers has published a 56-page reprint, 8½ x 11 inches, of 21 articles on the subject "Mow Drying of Hay" which appeared in the February, March, April, May, June, and July, 1947, issues of the Society journal, AGRICULTURAL ENGINEERING, and which were originally presented as papers before the Third Barn Hay-Curing Conference sponsored by the Society at Chicago in December, 1946.

Copies of these reprints may be obtained, as long as the supply lasts, from Society headquarters at St. Joseph, Michigan, at $1.00 per copy postpaid. On orders for 10 to 24 copies, the price is 70 cents per copy postpaid; 25 to 49 copies, 50 cents per copy postpaid, and on orders for 50 or more copies, the price is 30 cents per copy, but carriage cost is *not* included.

Necrology

DONALD L. HITCH was fatally injured July 4 in an airplane crash near Greaterville, Arizona, and died en route to Tucson in an ambulance. He was riding in a private plane piloted by his brother-in-law, Charles Culver, who was also killed when the plane crashed.

Mr. Hitch was born July 24, 1917, in Los Angeles, California, and spent most of his life in Tucson, Arizona. He was graduated from the University of Arizona in 1940, with a bachelor of science degree in agriculture, having majored in agricultural engineering. Shortly thereafter he was employed as assistant specialist in irrigation and soils in the agricultural extension service, University of Arizona. When the specialist, W. A. Steenberger, was called to war duties in 1941, Mr. Hitch carried on alone as acting specialist in the work. He had been promoted to specialist effective July 1, just preceding his demise. He was elected a Junior Member of A.S.A.E. in 1942, and a Member early in 1947.

Mr. Hitch is survived by his widow, Mrs. Ina Culver Hitch, a daughter, Ann Leigh, age 3; and his parents, Mr. and Mrs. Bertram L. Hitch, all of Tucson.

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Research Notes

(Continued from page 363)

Eight 4x10-ft cribs 10 ft high were built in the large grain storage building on the Agricultural Engineering Farm at Ames. Corn to fill them was all harvested by machine from one yield. It was found that the amount of husks depended more upon weather conditions than upon picker adjustment.

The corn in one of the cribs was rehusked clean by hand and showed only 0.9 per cent damaged kernels at the end of the storage period, whereas corn harvested from the same field at the same time and stored as it came from the picker developed 29.6 per cent damaged kernels during the same storage period.

Corn in the four south cribs had a lower moisture content than that in the four north cribs and the south location is considered more favorable than the north, but damage in each of the south cribs was somewhat greater than in the corresopnding north crib. It appears probable that the poorer storage results in the south cribs were due to the fact that these cribs contained about twice as much husks as those on the north.

The amount of loose shelled corn mixed with ears did not appear to be a big factor. Damage in one of the cribs was worse than in two others having twice as much shelled corn. Probably no crib contained enough to affect storage materially.

Results of this experiment, as of previous investigations, show that clean preparation is an important factor in the storage of corn having a high moisture content. Improvement in preparation can be made by careful operation and adjustment of the picker to husk as cleanly as possible, and by using a screen in the elevator at the crib to remove shelled corn and fine debris.

For harvesting corn of high moisture content, a picker with ample husking bed capacity and effective fan for blowing out loose husks and other light debris is preferable to a machine that lacks these features. Engineering research may find possibilities of further improvement of husking mechanisms.

* * * *

Agricultural Engineer Wm. E. Meek of the USDA Division of Farm Power and Machinery brought out his two model burners for flame-cultivators from the Delta Branch Experiment Station at Stoneville, Miss., and demonstrated them on the stage of the Plant Industry Station auditorium at Beltsville, Md., as he had previously done at the Philadelphia meeting of the A.S.A.E.

Since bottled gas, usually butane or propane, has replaced kerosene as fuel for flame cultivation, the practice has become much more effective and efficient and its use is steadily increasing. With the new double burners, flaming with sweep cultivation of the middles can be performed at a speed of 4½ mph.

Meek tells the cotton farmers that they can begin to flame when the cotton stalk is as thick as a 22-gage shell. Repeated flame cultivation not only keeps down weeds but tends to prune the lower foliage of the cotton plant. This makes mechanical harvesting much more successful.

New Bulletins

Electric Power, a popular bulletin picturing the past, present, and future of electricity on California farms, published by the California Committee on the Relation of Electricity to Agriculture. This 32-page, 8½x11-in booklet presents in pictures, drawings, and a few words, the development and significance of the application of electricity on California farms, and including specific reference to its applications in irrigation, fruit, nuts, truck crops, feed and grain, dairying, poultry raising, and the farm home.

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RATES: Announcements under the heading "Professional Directory" in AGRICULTURAL ENGINEERING will be inserted at the flat rate of $1.00 per line per issue; 50 cents per line to A.S.A.E. members. Minimum charge, four-line basis. Uniform style setup. Copy must be received by first of month of publication.

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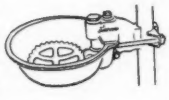

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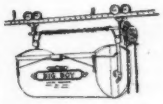
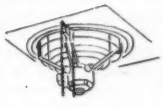
Save up to 30 minutes with Jamesway patented Lever Stalls. One handy lever locks all the cows in place—releases them all just as quickly. Easy to operate.



Save up to 50 minutes with a Jamesway "long-life" litter carrier. No other like it! One trip does the work of four or five with a wheelbarrow — and a lot easier.



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Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

M. Shamim Ahmed, representative, Government of India. (Mail) c/o William X. Hull, Soil Conservation Service, USDA, Washington 25, D. C.

Evan R. Allred, assistant professor of agricultural engineering, University of Minnesota, St. Paul 1, Minn. (Mail) 1426 Raymond Ave., St. Paul 8.

Elias Bloom, 274 St. John's Place, Brooklyn 17, N. Y.

W. O. Bower, instructor in agricultural engineering, University of Arkansas, Fayetteville, Ark.

Avery H. DeGolyer, assistant professor of agricultural engineering, Cornell University, Ithaca, N. Y.

Paul V. Faragher, metallurgist in charge of specifications, Aluminum Company of America, Pittsburgh, Pa.

Karl W. Fuge, structural engineer, James Mfg Co. (Mail) R. R. No. 2, Jefferson, Wis.

M. Dale Gilbert, sales engineer, Mason City Brick and Tile Co., Mason City, Ia.

Robert O. Gilden, assistant agricultural engineer, Washington State Farm Structures Research Assn., State College of Washington, Pullman, Wash. (Mail) 700 South St.

Ray W. Jones, soil conservationist, Mills County Soil Conservation District, Malvern, Iowa.

John H. Klas, director for Washington and Montana, Farm Market Relations, Inc., 1201 Northern Life Tower, Seattle 1, Wash.

Morel Leonard, manager, farm buildings and barn equipment division, United Co-Operatives, Inc., 243 E. Main St., Alliance, Ohio.

Robert D. McMichael, district farm specialist, General Electric Co. (Mail) 840 S. Canal St., Chicago, Ill.

Ewen M'Ewen, professor of agricultural engineering, Kings College, Newcastle-Upon-Tyne 1, England (Mail) 3 Kensington Terrace.

Charles D. Owens, Agricultural Engineering Bldg., University of Wisconsin, Madison, Wis.

Harvey S. Pardee, owner, Harvey S. Pardee & Associates, 549 W. Washington St., Chicago 6, Ill.

John E. Parisot, rural representative, Western United Gas & Electric Co., 50 Fox St., Aurora, Ill.

Gregory L. Pearson, 658 East 6th No., Logan, Utah.

Ralph K. Pease, co-owner and operator, Farragut Farm Supply, Farragut, Iowa.

Homer S. Porteus, farm structures dept., Celotex Corp., 120 S. LaSalle St., Chicago 3, Ill.

D. M. Ratnatunga, assistant engineer, Rolls-Royce, Ltd. (Mail) Over-Seas House, London, S. W. 1, England.

N. Sankara, estate civil engineer and lecturer in agricultural engineering, Government Agricultural College & Research Institute, Lawley Road, P. O. Coimbatore, South India.

Emil J. Voss, construction engineer, 1501 W. Louise St., Grand Island, Nebr.

TRANSFER OF GRADE

Robert L. Green, work unit conservationist, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Lawrenceville, Ga. (Junior Member to Member)

Walter E. Gross, senior rural representative, Pennsylvania Power Co., 19 E. Washington St., New Castle, Pa. (Associate to Member)

Homer C. Mauer, professor of engineering, Bluefield College, Bluefield, Va. (Junior Member to Member)

New Literature

PEST CONTROL HANDBOOK. Paper, 55 pages, 5¼x8¼ inches. Illustrated and indexed. Pest Control, Ltd. (Harston, Cambridge, England)

This bulletin describes the services offered by a British firm of consulting entomologists and agricultural spraying contractors. In doing so it gives a condensed summary of insect, weed, and plant disease pests of a variety of crops, and brief information on some control methods.

LEARNING TO WELD. Paper, 32 pages, 5½ x 8 inches. Illustrated. The Lincoln Electric Company, Cleveland, Ohio. 25 cents.

Instruction for the beginner on protective clothing and equipment, learning to strike an arc, welding beads on flat plate, types of welds, fit-up between plates, tacking plates, procedures for fillet welds in various positions, butt welds, corner and edge welds; welding cast iron, and hard surfacing. Tables for thickness, gap, and other variable conditions, and a glossary of welding terms are included.

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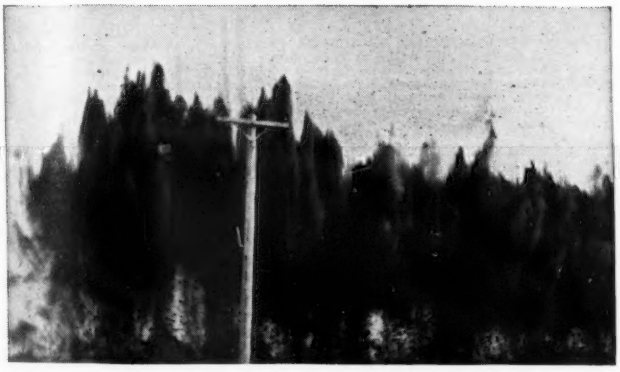

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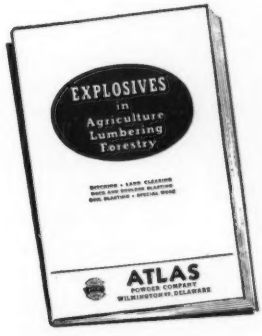

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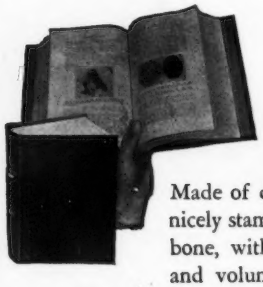

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Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this Bulletin the following listings still current and previously reported are not repeated in detail. For further information see the issue of AGRICULTURAL ENGINEERING indicated.

Attention is invited to the desirability of checking on the housing situation when considering a new location.

POSITIONS OPEN: 1946 MAY—O-503. JUNE—O-506. AUGUST—O-510. SEPTEMBER—O-516. NOVEMBER—O-523. DECEMBER—O-526, 531. 1947 MARCH—O-543, 547. APRIL—O-549, 551, 552, 555, 556, 557. MAY—O-558, 559, 560, 561, 562, 563, 564. JUNE—O-565, 567, 568, 569, 570, 571, 572, 573. JULY—O-574.

POSITIONS WANTED: 1946 FEBRUARY—W-207. APRIL—W-237. MAY—W-309. JUNE—W-320. SEPTEMBER—W-337. 1947 FEBRUARY—W-373. APRIL—W-383, 386, 387, 389. MAY—W-392, 394, 395, 397, 398, 100, 101, 102, 103. JUNE—W-104, 105, 106. JULY—W-107, 108, 109, 111, 112, 113.

NEW POSITIONS OPEN

AGRICULTURAL ENGINEER (instructor or assistant professor rank) for resident instruction in farm power, machinery, and related subjects, in a land-grant university in New England. BS deg in agricultural engineering, or equivalent. Experience in resident instruction or extension work in the technical field indicated. Must be cooperative and a good instructor. Opportunity governed largely by individual. Age, 25 - 35. Salary $3000 - $3780. O-575

AGRICULTURAL ENGINEER (associate professor) for teaching and some research in heat engineering, refrigeration, and related agricultural engineering subjects, in a land-grant university in the Southeast. MS deg in agricultural or mechanical engineering. Usual personal qualifications for teaching work. Age, 30 - 40. 12-mo basis, 30 days annual leave. Salary $4200. O-576

AGRICULTURAL ENGINEER (research assistant professor) for research in agricultural industries, services, and processing of farm products, in a land-grant university in the Southeast. MS deg in agricultural engineering, or equivalent. Usual qualifications for college work. Age, 30 - 35. 12-mo basis, 30 days annual leave. Salary $3600. O-577

AGRICULTURAL ENGINEER for research, teaching, and administrative work as head of the agricultural engineering department in a land-grant college in the Southwest. MS deg in agricultural engineering or equivalent, with advanced study in irrigation, farm structures, or farm machinery. Five to ten years teaching or research experience in fields indicated. Age, 30 - 40. Salary about $4200, depending on qualifications. O-579

AGRICULTURAL ENGINEER (assistant professor) for teaching farm structures, drainage and irrigation, and shop work, in a land-grant college in New England. MS deg in agricultural engineering or equivalent. Teaching experience or other work in fields indicated. Must have interest in teaching, and ability to hold the respect of students. Age, 25-35. 10-mo basis, with probability of permanent position, and normal annual raise of $180. Salary $3300. O-580

NEW POSITIONS WANTED

AGRICULTURAL ENGINEER desires research, sales, or service work with private company or government agency, in soil and water field. Particularly interested in hydrological research. BS deg in agricultural engineering, 1943, A. & M. College of Texas. Bureau of Reclamation 1 yr., hydrological engineer; U. S. Army, 3½ yrs., enlisted and commissioned service. Farm background. No physical defects. Available on one-month notice. Married. Age 26. Salary $3500. W-114

AGRICULTURAL ENGINEER desires sales, research, or teaching work in private industry or public service, in the fields of soil and water conservation, irrigation, and drainage. BS deg in agricultural engineering, 1938, A. & M. College of Texas. MS deg in agricultural engineering, Aug. 1947, A. & M. College of Texas. Ass't county agricultural agent, 6 mo.; engineering aide, U. S. Engineer Dept. (flood control surveys) 2 yrs; junior engineer, Soil Conservation Service, 2 yrs; commissioned service, Corps of Engineers, U. S. Army, 4½ yrs, including 3½ yrs mapping in southwest Pacific area. No physical defects. Available September 1. Married. Age 31. Salary open. W-116

AGRICULTURAL ENGINEER desires service, research, or teaching work in rural electrification. BS deg in agricultural engineering, 1943, University of Georgia. Experience 1 yr as assistant superintendent of REA Co-op, including work on right-of-way, staking, public relations, and utilization. Enlisted and commissioned war service in U. S. Infantry, Cavalry, and Transportation Corps. No physical defects. Available September 15. Single. Age 23. Salary open. W-117

AGRICULTURAL ENGINEER desires service work in private industry, preferably in field of soil and water equipment and structures. BS deg in agriculture, with major in agricultural engineering and minor in agronomy. Engineering aide, 3 mo., Soil Conservation Service; assistant to building contractor, 2½ yrs; enlisted war service in U. S. Coast Guard. No physical defects. Available on 2 weeks notice. Married. Age 25. Salary $2400. W-118